TRANSACTIONS

OF

THE FEDERATED INSTITUTION

OF

MINING ENGINEERS.

VOL. VI.—1893-94.

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Secretary.

Mr. M. Walton Brown, Neville Hall, Newcastle-upon-Tyne.

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TRANSACTIONS

OF THE

FEDERATED INSTITUTION

OF

MINING ENGINEERS.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE ROOMS OF THE ROYAL SCOTTISH SOCIETY OF ARTS, EDINBURGH, AUGUST 12TH, 1893.

MR. J. B. ATKINSON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected by ballot:—

FEDERATED MEMBERS.

Mr. ERNEST SELLERS, Metropolitan Colliery, Helensburgh, New South Wales.
Mr. JOHN HOWIE, Machan Colliery, Larkhall.
Mr. ROBERT FORRESTER, Castle Gate, Emery Co., Utah, United States.

DISCUSSION UPON MR. J. B. ATKINSON'S ADDRESS ON "THE MINING FIELDS OF SCOTLAND."

Mr. JAMES PRENTICE (Airdrie) wrote that he was somewhat reluctant to reopen the discussion of the President's paper, especially as it had been so recently closed, but the communication from Mr. Mottram,* dealing with the geological position of the Canobie coal-field, makes it possible for the writer to bring further evidence of a purely geological nature to bear on the same subject, and as Mr. Mottram's arguments, as well as the writer's, are directly opposed to the theory of the Geological Surveyors, the

* *Trans. Min. Inst. of Scot.*, vol xiv., page 261.

importance of the question involved is a sufficient warrant for this unusual course. The officers of the Geological Survey would be the last to claim for their work that it is anything like perfect, and indeed the more one thinks of the immense amount of labour involved in their gigantic work, the diversity of opinion of the officers, and the complex nature of the data from which their deductions are drawn, the more one wonders that their work is so free from defects. The writer therefore thinks, that, had the facts as they are recorded in Mr. Mottram's remarks been known to the officers of the Geological Survey, they certainly would not have classed the Canobie coal-field as belonging to the Calciferous Sandstone series. The writer may be permitted to remark here that it is largely through Institutes, such as this, that the discovery and rectification of any errors in the published work of the Geological Survey is now possible, and so far at least as the Carboniferous system is concerned this may be considered their national duty. The remarks of the President, upon which this discussion is based, are as follows:—

> At Canobie, in Dumfries and close to the Border, a colliery is working seams of coal in either the Carboniferous Limestone or Calciferous Sandstone series. The Geological Survey places these coals in the latter division of the Carboniferous system, but if this is so it is not in harmony with what is observed in the Calciferous Sandstone elsewhere in Scotland, where, with the exception of the Houston and one or two other thin coals, no suite of coal-seams occur such as exist at Canobie. It has been concluded by the Survey that the Canobie coal-seams are contemporaneous with the Scremerston seams in North Northumberland. The Scremerston seams underlie a limestone known as the Eelwell limestone, which is thought to correspond with the Hurlet limestone in Scotland. If this reasoning be sound, the Canobie seams are in the Calciferous Sandstone, but in the meantime it will be assumed that they are in the Carboniferous Limestone. The Canobie coals dip southward under newer rocks.*

It is evident from the above remarks that the President does not accept the views of the officers of the Geological Survey, but quietly exalts the coal-field into the Carboniferous Limestone series, and leaves it there severely alone. Mr. Mottram places this coal-field in a still higher position, and gives reasons proving that it ought to be classed with the Upper Coal-measures, quoting from records of boreholes, and other sections of the strata. The writer entirely endorses his conclusions, and thinks that Mr. Mottram makes out a strong case in favour of his view. It is perhaps in accordance with the eternal fitness of things that the *coup de grâce* to this theory of the Geological Survey should be delivered by a weapon from their own armoury. This weapon is found in the word "mussel-band," which occurs twice in Mr. Mottram's remarks, as follows:—" . . . . the upper coal-seam lying at a depth of 23

* *Trans. Min. Inst. Scot.*, vol. xiv., page 212.

fathoms, with the mussel-band, 10 inches thick, 4 fathoms underneath. . . . . At a depth of 262 yards the upper coal and mussel-band were found . . . ." The writer may explain that mussel-band is a mineral formation of a peculiar and easily recognized appearance. It is an agglomeration of fossilized shells, chiefly *Anthracosia acuta* and *Anthracosia robusta*, cemented together by a mixture composed of varying proportions of iron, lime, silica, and alumina, with a little bituminous matter. It occurs in bands of from 1 to 4 inches, or in thin seams of 4 to 10 inches in thickness. Its range is throughout the whole of the Upper Coal-measures, and generally the thinnest bands are nearest the bottom of the series. Its occurrence is not unfrequent; probably there are as many as nineteen or twenty well-defined separate bands of this mineral found at intervals throughout the Upper Coal-measures in Lanarkshire and Ayrshire. Mussel-band has never been found in the Millstone Grit, Carboniferous Limestone, or Calciferous Sandstone series, and it may be accepted as a geological axiom, that any seam of coal that may have a seam of mussel-band in the strata associated with it, must of necessity belong to the upper coal-measures. It is unnecessary to pursue this subject further, although the evidence is by no means exhausted. This question is one of national importance, and if these proofs be correct, instead of the Canobie coal-field being a thing of shreds and patches representing the first efforts of nature when trying her 'prentice hand in the formation of coal, it is a fully developed coal-field with probably the very highest coal in the Upper Coal series represented, dipping away into the northern counties of England. Further, the probability of productive coal-measures being found under the red measures (coloured as Permian on the map accompanying the President's paper), and lying to the south and east of Dumfries, becomes almost a certainty. The red sandstones, found on the surface over a large area in this district, were long thought to belong to the Old Red Sandstone formation, and consequently to be barren as far as coal was concerned; but recently they have been classed as belonging to the New Red or Permian formation. They are exactly similar to the rocks to the south of Canobie which have been proved to overlie the coal-measures, and probably before long, active search will be made in this district for new coal-fields.

In the absence of the author the following "Notes on Work done by the Stanley Heading-machines at Hamilton Palace Colliery," by Mr. James S. Dixon, were read by the Secretary :—

NOTES ON WORK DONE BY THE STANLEY HEADING-MACHINES AT HAMILTON PALACE COLLIERY.

BY JAMES S. DIXON.

Owing to the circumstances of this coal-field it was considered desirable to use some other means than hand labour to more quickly drive into and open up the workings. With this object in view the Stanley heading-machine was adopted.

These machines are driven by compressed air, and as with all machines it is essential to success to have an ample supply of motive power, a few notes on this head may be of interest.

A set of air-compressors were put down, with double steam and air-cylinders, each 20 inches in diameter by 3 feet 6 inches stroke. The air-cylinders are fitted with the Walker system of valves, which form the feature of their construction. The pistons of the air-cylinders are coupled direct to those of the steam-cylinders, and are usually driven at about 18 revolutions per minute. The air is compressed to a pressure of 60 lbs. per square inch, and is received into a steel boiler, 28 feet long by 6 feet in diameter, placed in the engine-house. The air passes through about 90 feet of cast-iron pipes, 18 inches in diameter, towards the top of the pit, and by 6 inches pipes down the shaft to a second receiver, 25 feet long by 4 feet in diameter, a distance altogether of about 350 yards from the engines. From the pit-bottom it is conveyed by 6 inches pipes a distance of about 1,150 yards to a third receiver, 25 feet long by 4 feet in diameter; thence by 7 and 6 inches pipes a further distance of 235 yards, and by 400 yards of 2 inches malleable iron pipes to the machines, which are connected to this pipe by short lengths of flexible hose, 2 inches in diameter.

As before stated, the air in the first receiver in the engine-house has a pressure of 60 lbs. per square inch, and that pressure is maintained without appreciable loss in the second and third receivers. At the end of the 2 inches pipes, close to the machines, with these not working, the pressure is about ½ lb. less, but when the machines are at work it falls to about 15 lbs., owing no doubt to the friction in the long length of 2 inches pipes.

Besides working the two heading-machines, the compressed air actuates eight pumping-engines, and one hauling-engine of the dimensions, and doing work as follows, viz.:—

Description.	Air-cylinders.		Diameter of Pump.	No. of Strokes per Minute.	Hours Worked per Day.
	Diameter.	Stroke.			
	Inches.	Inches.	Inches.		
1 Worthington pump, double ...	3	3	2	150	8
1 Tangye pump, single	4	11	3	120	20
4 " "	6	12	4	40 to 60	10 to 24
1 Cameron pump, double ...	6	6	4	40	12
1 " " ...	7	6	5	40	10
1 Hauling-engine	9	18	—	130	1½

These air-compressors have been at work night and day since December, 1888; and as they are working well within their capacity, they have given little trouble. As all the workings are below the level of the pit-bottom, and as troubles cause many depressions, the use of compressed air underground has been of great advantage irrespective of its use in the coal-cutting machines, for which it was originally introduced.

The Stanley heading-machine has already been fully described by Mr. R. Stanley* and by Mr. G. Blake Walker.† It may, however, be briefly described as consisting of a frame carried on two wheels set tandemwise, one in advance of the other. This frame carries an engine with two cylinders, and the engine-shaft is geared to the principal cutting-shaft, which passes through the centre of the frame. On the end of the principal shaft a cross-head is fixed, carrying at right angles the two arms upon which the cutters are fastened. The object to be accomplished is, by the rotation of the cross-head and arms, to cut an annular groove in the face of the heading.

The machines adopted at Hamilton Palace colliery make a cutting 5 feet in diameter. The cylinders are each 9 inches in diameter by 9 inches stroke, geared to the central cutting-shaft as 13 to 1. This shaft has a screw thread cut nearly its whole length, by which, and suitable gearing, the cutters are advanced. The arms project about 3 feet beyond the cross-head; and this length controls the extreme depth of each cut. The machine is anchored to the sides and floor to maintain it in position, and to keep the cutters against the face. When a cut the length of the arms has been made and the coal removed, the cutting motion is put out of gear and the advancing motion put into gear, by which the whole machine is propelled forward to begin anew.

The small coal made in cutting the groove, which is about 3 inches wide, is raked or shovelled back by a man placed at the side of the

* *Trans. Chesterfield Institute*, vol. xvi., page 192.

† *Trans. Fed. Inst.*, vol. i., page 124.

machine at first, and as the cross-head advances he can work in front. The centre core of solid coal generally breaks down, and is removed once or oftener during each cut; and if any remain it is taken down by picks or wedges. The actual cutting by the machine is done very rapidly as will be afterwards shown, most of the time being occupied in removing the coal and shifting and re-fixing the machines.

At Hamilton Palace colliery, the first trials were made with one machine; but it was soon found that the exhaust air was insufficient to keep the place clear of fire-damp; and a continuous blower of compressed air likewise failed, besides being a most expensive mode of ventilation. There was also difficulty from water, as the leading places dipped sufficiently and allowed it to accumulate at the face. A hole 5 feet in diameter gives no facilities for bratticing, and few for leading in pipes, loading coal and carrying on the work.

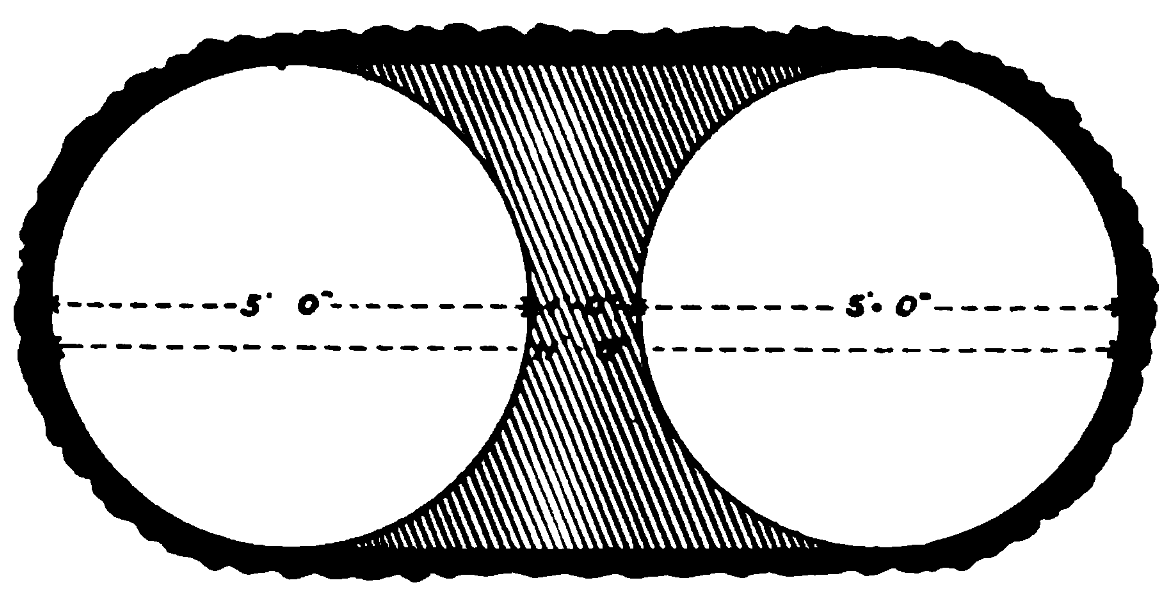


FIG. 1.

As the usual haulage roads are 11 feet wide, it was resolved to try two machines, one working immediately in front of the other. These are driven so as to leave between the drifts about 1 foot of coal, which is to some extent utilized as a bratticing for guiding the air, and is afterwards removed, leaving the roof flat with curved sides, which stand well (Fig. 1). This manner of driving gives room for ventilation, loading, and removing the coal, and following up with pumps and pipes when necessary.

The heading-machines have been at work since December, 1888, and during that time have cut about 3,000 yards of places 11 feet wide in the ell coal-seam, and about 800 yards in the splint coal-seam. The ell coal-seam is about 7 feet and the splint seam about 6½ feet in thickness, so there is ample room for the 5 feet cut. In some parts, the ell coal-seam had blaes (shale) partings from 1 to 3 inches in thickness, but these and the harder nature of the splint coal-seam, and its accompanying cannel coal, made little or no difference in the work done by the machines. In some places, where small slips intervened, either the roof or the pavement,

which are strong fakes and hard fireclay respectively, was encountered and cut through for short distances without difficulty.

After considerable experience, the plan adopted, as the most efficacious, is to drive the places in pairs, the leading places being about 100 feet apart (Fig. 2). The dip place is driven a distance of about 200 to 300

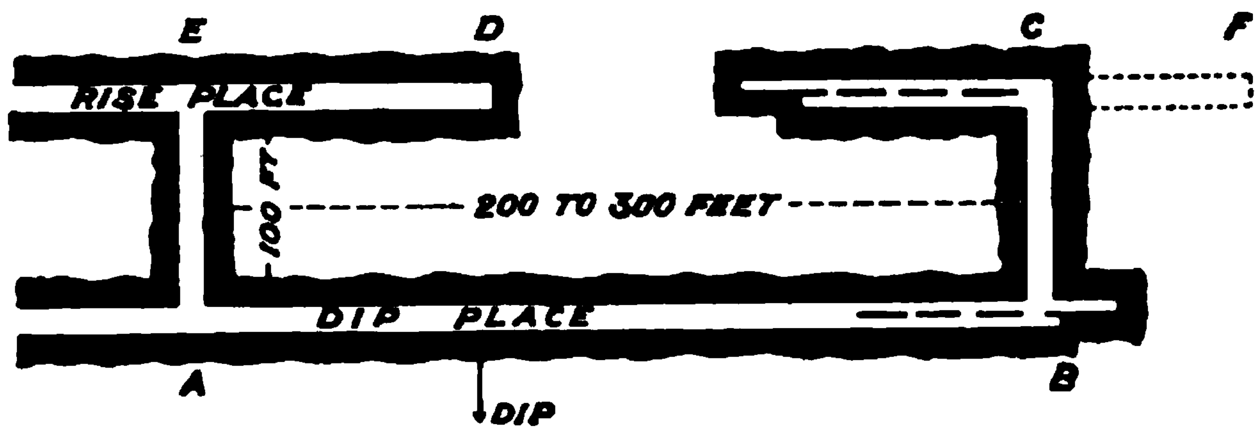


FIG. 2.

feet in advance from A to B, the cross-cut (B to C) is then made. The machines are then turned backward at C, so as to drive a place in the direction of D, and meet the rise place which had previously been driven 50 to 100 feet in advance of the former cross-cut E. When the rise place C E is holed through, the machines are drawn back to C and the rise place driven from C to F in advance (as at E to D) as far as convenient. The machines are then transferred to the face of the dip place at B, and the entire process repeated.

Under favourable circumstances, such as places going to the rise, sufficient to allow of water flowing away, distances of a length of 650 feet have been driven without cross-cuts. By the mode of driving, above described, a certain amount of progress is lost (though it was found necessary, to enable a sufficient current of air to be well up to the face), but by employing 3 or 4 machines continuous progress could be made. As the merits of any such machine can only be judged from the actual work done over a period of time, the following record was kept when a comparatively clean and continuous area of coal was being operated upon, with the following results, viz.:—

Fort-nights.	Shifts Worked.	Distance Cut 5 Feet in Diam.	Distance Cut per Shift.	Amount Paid for Cutting and Filling.	Cost per Lineal Foot Cut.
		Feet.	Feet.	£ s. d.	s. d.
1	23	283	12·30	35 9 9	2 6·09
2	23	270	11·74	33 3 9	2 5·50
3	24	276	11·50	31 4 6	2 3·15
4	18	212	11·77	23 8 2	2 2·50
5	19	230	12·10	20 18 0	1 9·80
6	23	284	12·34	24 19 6	1 9·10

There was a reduction of wages during the two last fortnights, hence the lessened cost.

As previously mentioned, the time occupied by the machines in cutting is comparatively small. The following is a record kept of actual work done, viz.:—

	Hours.	Mins.	Hours.	Mins.
Time at work, exclusive of meals	...	...	8	14
Cutting at the face	1	18		
Breaking down and throwing back the coals	3	43		
Shifting and re-adjusting the machines ...	3	13		
			8	14

During this time, 5 men were employed, the distance cut was 15 feet 1 inch, and 10 tons 2 cwts. of coal was produced. The earnings of the 5 workmen were about 5s. per shift, so that the coal was costing for their labour about 2s. 6d. per ton.

The conclusion arrived at, after all the experience gained, is that, in these coal-seams, the Stanley heading machine drives a place 11 feet wide about four times faster than hand labour, at about double the cost.

Mr. James Hamilton read the following paper "On the Report of the Royal Commission on Mining Royalties":—

ON THE REPORT OF THE ROYAL COMMISSION ON MINING ROYALTIES.

By JAMES HAMILTON.

The prolonged depression of trade which followed the abnormally active period of 1873-74 has been characterized by many improvements in mining. It has illustrated the uses of adversity and, from a scientific point of view, has amply repaid the anxiety it occasioned. One result directly traceable to it is the discussion of the laws affecting the ownership of land and minerals. So violent has this discussion been in some quarters that it might almost be described as an agitation against the system of mining royalties.

For years we have been told that mining royalties are a tax upon industry; that they handicap the nation in competition for the trade of the world; and that their abolition is absolutely necessary in order to revive our languishing industries. Some of the more advanced theorists have advocated the nationalization of land and minerals, and even of mines, as the only remedy for what they consider a crying evil.

The evidence of Sir Lowthian Bell given before the Commission on the Depression of Trade, in which he contrasted the amounts paid in royalties on a ton of manufactured iron in this country and in foreign countries, was largely responsible for the form assumed by the agitation. It was an apple of discord to that Commission itself, for no fewer than four several dissents from the majority report thereon were recorded.

In the course of this agitation, many extraordinary estimates of the amount paid in royalties in the United Kingdom were made. They ranged in amount from six million to seventy million pounds per annum, and from eight to thirty per cent. of the value of the gross output. Various attempts at legislation were made in the next few years, all more or less in favour of lessees. These attempts all failed, and served only to accentuate the absence of accurate knowledge on the subject already abundantly apparent.

Evidently the first necessity was information, and the Government in 1889 appointed a Royal Commission of a thoroughly representative character, and consequently composed of the most diverse elements, suggestive of the proverbial happy family. There were twenty-one

members, with Lord Northbrook as their chairman. All mining interests were represented—proprietors and proprietors' legal and mining advisers, colliery and metalliferous mine-owners and their agents; lawyers, economists, and the more staid and conservative section of the miners as well as the more advanced and revolutionary. The Commission was instructed—

To enquire into the amounts paid as royalties, dead-rents, and way-leaves on coal, ironstone, iron-ore, shale, and the metals of mines subject to the Metalliferous Mines Act, 1872, worked in the United Kingdom, and the terms and conditions under which those payments are made, and into the economic operation thereof upon the mining industries of the country, and further to enquire into the terms and conditions under which mining enterprise is conducted in India, the Colonies, and foreign countries by the system of concession or otherwise and the economical operation thereof.

The enquiry has just been completed, after upwards of three years' labour, and the results are now before the public in five bulky blue-books, containing more than twenty thousand questions and answers; and tables, diagrams, and appendices without number.

One of the first and most important effects must be to clear away the confusion of thought which was a striking feature of the discussion and agitation leading up to the appointment of the Commission, and to shatter what has been a very effective weapon in the hands of men skilled in the means of raising public clamour. Now that the report is in their hands royalty owners may breathe freely, if indeed they ever contemplated the result with aught but calm confidence in their own integrity. The beneficial effect of the enquiry is already evidenced by the rapidity with which the subject has ceased to interest, a result helped, no doubt, by the swing of the trade pendulum towards the prosperous side.

In carrying out the enquiry entrusted to them the Commissioners issued a series of questions to coal-owners' associations, and to a committee of royalty owners, with the object of eliciting information as to the conditions of mineral leases, fixed rents, and royalties charged, and the methods of assessing them; the provisions affecting surrender and assignment, way-leaves, and shorts; and generally any question or matter considered as a grievance, or which it was desired to bring before the Commissioners. The various associations were afterwards allowed to support their replies by verbal evidence. Miners' representatives were also heard; and information upon foreign and colonial systems was obtained both by circular and by examination of experts.

The total amount of royalties and way-leaves paid on minerals in the United Kingdom during 1889 are shown in the following table; it being

noted that so far as the figures apply to England and Ireland they are merely estimates, based upon the output for the year, and such information as to average royalty in various districts as was elicited in evidence, together with the personal knowledge of the Commissioners.

	Output, 1889. Tons.		Royalties. £		Way-leaves. £
Coal—					
England and Wales ...	153,596,360	...	3,374,235	...	188,100
Scotland	23,217,163	...	629,902	...	13,816
Ireland	103,201	...	4,216	...	—
Totals	176,916,724	...	4,008,353	...	201,916
Ironstone and iron-ore—					
England and Wales ...	13,319,685	...	525,239	...	14,781
Scotland	1,061,734	...	33,824	...	
Ireland	164,686	...	2,059	...	
Totals	14,546,105	...	561,122	...	14,781
Totals—					
Coal	176,916,724	...	4,008,353	...	201,916
Ironstone and iron-ore ...	14,546,105	...	561,122	...	14,781
Other metals	—	...	87,068	...	—
Totals	—	..	4,656,543	...	216,697

The royalties per ton upon coal in the various mining districts are estimated as follows:—

Coal-fields.	Maximum.	Minimum.	Average.
	s. d.	s. d.	s. d.
Northumberland	0 10	0 2½	0 4
Durham	0 10	0 2½	0 5
Cumberland and Westmoreland	0 8	0 3	0 6
Lancashire and Cheshire	—	—	0 6
Yorkshire	—	—	0 6
North Staffordshire and Cannock Chase	—	—	0 5½
South Staffordshire, Warwickshire, and Worcestershire	0 8	0 3	0 6
Derbyshire, Nottinghamshire, and Leicestershire	0 6	0 4	0 4¾
Shropshire	—	—	0 6
Somersetshire	0 9	0 5	0 6
Gloucestershire—Bristol	—	—	0 6
" Forest of Dean ...	—	—	0 3
Monmouthshire and South Wales ...	0 9	0 4	0 6
North Wales	0 10	—	0 4
West Scotland	1 3	0 4	0 7
Fife and the Lothians	1 2	0 3	0 6

Whatever the procedure by which minerals in the United Kingdom became private property, there is no disputing the fact that, with the exception of gold and silver, they are now as a general rule vested in the surface owner, and nationalization is therefore only possible by compensa-

tion or by confiscation. If an attempt were made by compensation it would not, in the opinion of competent witnesses, be a profitable undertaking for the State at the price that would be assessed by valuators; while even the most extreme witnesses hesitated to advocate confiscation when placed in the witness box—a situation which exercises a salutary and subduing effect on most men. As to this policy of nationalization it is curious to note that new countries generally are not directing their policy to avoid private ownership either of land or minerals, but are following a policy which will bring them exactly into the position in which we in this country now find ourselves. They are doing this with their eyes open. While European nations had not the experience of older countries in this matter before them as a warning or example, it is far otherwise with the Colonies and America; and, judging from their policy, they see nothing to alarm them in the results of our system. The government of the United States, for example, retains neither land nor minerals as national property, but freely disposes of both to individuals or corporations. An American witness said "The object of the Government then is to develop the mineral resources, . . . and to get a clear title into the hands of a citizen as rapidly and as cheaply as possible, and then to take its own hands off."* The troubles that have arisen out of separation of ownership of surface and minerals prove in our own experience the wisdom of that course, and a new country with its need of men and capital finds its strongest attraction in the land hunger firmly rooted in the breast of every man.

Separation of the ownership of the surface and mineral, when the latter belongs to the State, was found long ago in Scottish history to make it the interest of the surface-owner to conceal or prevent the discovery of minerals on his land. No good, certainly much trouble, and possibly some loss, must inevitably come to him by the working of minerals on his land; and this has no doubt been a factor in producing individual ownership. In some of the Australian Colonies a somewhat similar difficulty is being experienced.

All things considered, it is by no means certain that private property in minerals is a disadvantage. Given State ownership of mines with or without land also (the nationalization of land and of minerals is really but one question), and we have many unsolved difficulties to face which were far from successfully met by those who advocated the change before the Commissioners.

There is, for example, the question of how to prevent royalties or their equivalent from springing up. Unless worked as a State department it is

* Third Report, page 15, question 14,385.

difficult to see on what system the mines are to be worked, and that alternative is a risky one. If leased to private parties, no satisfactory means of selecting the lessee has been suggested other than by competition. A fixed royalty has been proposed, but no witness could say how a tenant should be chosen when two or more offer the same fixed royalty for a mineral field. To proceed by concession based on the right of discovery is impossible in this country where the mineral resources are so well known. Under any system of concession, even if a concessionaire be forbidden to sell or sub-let, the royalty inevitably comes in. Death ultimately claims concessionaire or tenant, and his property must be realized—presumably by sale in the open market. The price paid by the purchaser, over and above the value of the machinery on the ground necessary for working the mines, takes the place of a royalty, inasmuch as it is his estimate of future profits from the concern and includes the capitalized equivalent of a royalty. Then, as one witness put it, if there were no royalty there would be no landlord to squeeze in times of depression. The witnesses were unanimous in preferring to deal with an individual landlord, rather than with a Government department, hampered by being in trust for the State, and with the certainty of criticism and the uncertainty of what use their political opponents might make of their actions whatever they might be.

In this connexion take the opinion of an American witness* :—

The payment of royalties . . . has assisted the development of the minerals of the United States. My reason for saying that is, that I have had a chance of observing in the Western United States, for a period of nearly twenty years, the operation of a system without royalty, namely the system of free license to mine on the public lands, and I have found there that an element of stability and progress and of real regulated industry was introduced, when these public lands were made private property, which is only to say in other words when they were made subject to royalties. It seems to me that in our country, so far as we have got with the question, waiving all difficulties, which you may have encountered in your more advanced position of development; in our country, it is perfectly well illustrated that private property and the enlightened self-interest of private owners is a far better atmosphere for the development of a regulated and a prosperous industry, than any amount of free gift on the part of the State. We went and made every mine on the Pacific Coast from the Rocky Mountains to the Pacific Ocean free of royalty, and we just had chaos, anarchy, and no progress, no stable order, no clear and definite title. Then we went laboriously to work, and have at last got it round, so that the principal mines are in private hands, and they charge whatever royalty they can, and we have got more industry, and more safety and security and profit by introducing the principle of private responsibility and private interest. Until anybody can show me a case where the opposite has taken place, I must confess that I feel as if that was, for my country in its present condition, a conclusive answer

* Third Report, page 19, question 14,452.

to the whole subject. I have been accustomed to say at home over and over again that it would be better for the United States to-morrow, to give up all its mineral land and deliberately convey it to individuals for nothing, in order to have somebody own it instead of the Government.

It was shown in evidence that in Spain where the minerals are granted by concession to individuals, the concessionaire generally occupied the position of a landlord here, disposing of his concession to the actual worker of the minerals, reserving a royalty, or obtaining a capitalized equivalent of a royalty, by a sale of his concession.

In other European countries the position is practically the same, although, theoretically, in some cases, there are restrictions upon the liberty of the concessionaire in the matter of sub-letting, and in the power to resume a concession in certain circumstances. These conditions are rarely or never enforced, and property in minerals is practically as absolute as that of a freeholder here. The concessionaire seldom leases his minerals; but he as seldom works them himself, finding it more to his advantage to sell his right.

By whatever system the State deals with mineral property it appears that the royalty system or an equivalent inevitably comes into operation, and any attack on royalties as such is as futile as beating the air.

State ownership of minerals, though clearly not the unmixed good its advocates claim, has certain advantages. It affords greater facility for working minerals economically, for dealing with way-leaves, and for arranging and working mine-drainage schemes, which grow in importance with the age of our coal-fields, and will be a difficulty to be overcome by future generations of mining engineers. These advantages, however, can only be secured by avoiding the system of concession, and by keeping the letting of minerals in the hands of a State department, to be worked with the object of getting for the State the fair value of its property for the benefit of the nation. But nationalization is not meantime within the range of practical politics, and it is unnecessary to discuss it further.

It has been pointed out by various authorities that a mineral lease is not a lease at all, in the ordinary sense of the word; as applied to agriculture, for example, where the value of the leasehold is not diminished, but, by careful husbandry, is maintained, if not enhanced. Under a mineral lease there is no increase, but the removal of part of the property and a consequent diminution of value. The instrument under which the lessee works is thus really a sale of part of the property. Hence the necessity for a payment proportionate to the quantity of mineral removed, and also for a fixed minimum rent; the former to secure to the landlord a revenue

from his property equivalent to decrease in value, and the latter to prevent the locking up of the minerals without any return at all. The need for this double security was very early recognized in the North of England and in Scotland; for in almost the earliest leases extant, alongside the stipulation of a fixed rent the maximum number of hewers is agreed upon, a somewhat crude method of meeting the case, but doubtless sufficient for the needs of the time.

This has not apparently been so early recognized farther south, or if recognized has not been acted on, as cases are comparatively common in Wales where very long leases of large areas of mineral property are, or were lately, in force under fixed annual rent only, and miserably inadequate rent at that. It is stated that the Dowlais Iron Co. paid only £100 per annum for a century prior to 1847; and in 1848, when a lordship was stipulated under a new lease, upwards of £20,000 was paid for the year's output.

The landlord being thus protected by a fixed rent, the lessee seeks to secure himself against loss of shorts or overpaid fixed rents by stipulating for the right to work, free of lordship, coal equivalent thereto, generally limited to a certain period, to make up shorts. The English coal-owners appear to consider this limitation of the time to recoup overpaid fixed rents as very much of a grievance; but without it a fixed rent is no adequate protection for a lessor against the locking up of his minerals, while on the other hand the lessee seeks greater security for capital outlay by taking the largest field he can get at the lowest possible rent. If greater security for capital invested is desired by a leaseholder he must pay for it by increased fixed rent, in order to induce the proprietor to give him a larger field. The amount of the rent is, or ought to be, determined so far as a lessee is concerned, not by the area of mineral field, but by the amount of mineral he can—one year with another—raise and dispose of. To the lessor the determining factor is the area, and the conflicting interests will be compromised in favour of the party in the stronger position under economic laws. So long as the parties are in a position of equality, a fair and reasonable bargain, so far as their information goes, will be struck. But if we should call no man happy till he is dead, so we call no mineral lessee fortunate till his lease is discharged. Difficulties may arise in winning and working which were not anticipated and which it was impossible to forecast, and the working of the minerals thereby so delayed that the lessee is unable to work up his shorts; in other words he pays for mineral which he is unable to work. It is true that if the lessee insists on having a large field and greater security for his

capital it is fair he should give an equivalent; but in this matter at least the risks, because unknown and incalculable, are mainly with the lessee.

In the circumstances, probably few will object to the conclusion of the Commission in favour of some such remedy as was provided by the Bill introduced into the House of Commons in 1888, "Giving the Court of Chancery power to give the lessee, if the non-extraction of the mineral was not owing to his default, a period of grace in which to work the coal for which he has paid without further payment of rent, unless the landlord elect to repay the overpaid rent instead."*

The principle of compensation for unexhausted improvements at the end of a lease was urged by some associations and individuals; but it is dismissed with a summary of evidence given before the Commission. In Scotland, practically the only permanent improvements for which a tenant does not receive compensation are the shafts, permanent roads in workings, formation of railways, sidings and other earth-works, which are of no value to him, and of little to the proprietor unless the colliery is to be continued without any interval. But as anything which reduces the unknown risks to a lessee must be alike to his and to the lessor's advantage, it appears a legitimate direction for reform.

Evidence was brought before the Commission tending to prove hardship in the restriction of the right of a tenant to assign his lease. Such right of assignation is, from a lessee's point of view, a very desirable stipulation, and, with sufficient safeguards, not unfair to a lessor. While a clause precluding assignation is almost universal in mining leases, it appears that "a covenant in restraint of alienation in the case of a mining lease is not regarded by the court as a usual covenant;" and that, consequently, an agreement to enter into a formal lease with all the usual covenants, does not entitle the lessor to insist on a clause excluding assignees. Inasmuch as the Conveyancing and Law of Property Act appears to proceed upon the principle that covenants against assignation should only be used for the reasonable protection of a lessor, and not as a means of exacting money by way of fine, the Commission consider that it would not be an undue restriction upon freedom of contract if it were provided that all covenants against alienation be held to mean, that it is not to be done without the proprietor's consent, and that such consent shall not be unreasonably withheld. This appears to meet the case of the lessee (as brought forward in evidence) in a way that gives fair protection to the lessor, its weakness being the indefiniteness of the expression "unreasonably with-

* Final Report, page 16.

held;" but that is an objection which may be urged against all legislation, and the interpretation may be safely left to arbitration, or to the courts.

The Commission do not favour the creation of a special tribunal to deal with mining questions such as shorts, compensation for improvements, etc., considering the advantages of such a court not sufficiently established by the evidence.

An important part of the case laid before the Commission by coal associations, particularly by those of the North of England, referred to way-leaves. This being the oldest mining locality in the kingdom, and collieries having been established before public railways were in existence or sufficiently developed to meet the needs of the district, many of the collieries have private lines connecting the pits with the shipping-places on the Tyne. These lines are way-leave lines, and payment has to be made to the proprietors of land passed over for right of way. Hence the greater importance of this question there. This is shown by the estimated proportion of output subject to way-leave:—Northumberland $\frac{1}{3}$, Durham $\frac{1}{2}$, Yorkshire $\frac{1}{4}$, Monmouth and South Wales $\frac{1}{3}$ (in other parts of England payment for way-leave is only made in exceptional cases). For the whole kingdom the proportion is less than a $\frac{1}{4}$. It was contended for those opposed to way-leaves, and the evidence was principally from mine-owners, that payment for way-leave ought to be determined by the damage to the grantor of the right, and not by the value of the right of way to the grantee. They did not ask to be let off for the mere agricultural value of the land taken, but were quite willing to pay full value for any damage of whatever kind, for amenity or for intersection. It was held, unassailably from their point of view, that the damage to the grantor of the way-leave was not proportionate to the amount carried over the ground, but is the same for 1 ton as for 1,000, and that, therefore, the demand for a tonnage rate over and above the payment for damage done is not at all a fair one. Many instances were given in evidence, in a very effective way, of the annual payment per acre for ground occupied for way-leave purposes, being many times the full market value of the land. One instance cited by a witness may be mentioned as a kind of *reductio ad absurdum* of way-leaves. A mine-owner worked coal from an enclosed common where, as is usual in such cases, there was severance of ownership of minerals and surface, the former belonging to the lord of the manor. For purposes of drainage a shaft existed on the property of a certain small surface-owner, who could not and did not exercise any restrictive right to the operations of the coal-master, so long as he drained only the coal of the lord of the manor by

this pit. But in course of time the colliery owner leased and worked coal belonging to an adjoining proprietor, and naturally the water therefrom mingled with the water from the coal of the lord of the manor and was raised by the pumping shaft referred to. The surface-owner threatened interdict unless the coal-master came to terms with him, and he obtained a way-leave rent of £100 per annum on a property of 25 acres, which the witness valued at 5s. per acre.

It was contended by witnesses on behalf of the proprietors, that way-leaves are easements—payment for a certain privilege, and as such are not assessable on the basis of the damage to the grantor of the way-leave but upon the value of the easement to the grantee; that the way-leave may be looked upon as merely part of the cost of conveyance to the market; and that, in the case of the North of England at least, the way-leave lines made before the public railways by arrangement with the several landowners, were made much more cheaply than the public railways, and that conveyance by the former, including payment of way-leave, is cheaper than by the latter. They held that a case had not been made out for legislative interference with the present system, that it was not a question of public concern, but affected only the parties themselves; and that the right to acquire land compulsorily in such circumstances was not such as would be granted by Parliament, but was indeed contrary to the principle upon which powers are granted under private bill legislation. This latter point was abundantly proved.

The term way-leave means simply right of way or leave of way granted by a proprietor through or over his property for a given purpose, and this necessarily implies, under the very absolute rights of ownership recognized by our laws, the full power of an owner to refuse or grant the right on what terms he pleases.

That it is a leave of way also implies that it is, to the person obtaining it, an easement which has to him a certain value, quite independent of the damage done to the owner. Given conditions under which the parties negotiating are on a complete equality, the presumption is that the bargain, if struck, will be fair to both parties. But this is just the condition very frequently absent in such cases, which, from the very nature of the right, gives the grantor complete command of the grantee, and enables him, if he will, to take advantage of the necessities of the latter to his own profit. Perhaps no question was more thoroughly thrashed out in evidence than this, and it is an eloquent fact that although very strong language was used by several coal-owners' associations, no thoroughly authenticated case of minerals being left unworked through refusal of a

way-leave was brought out, and the coal-owners' associations, from whom most of the evidence came, are left with the rather poor consolation of being told that:—

It is probable that occasionally exorbitant charges are made for this description of easement, but we have received no evidence on behalf of the associations who made the complaint to show that the difficulty extensively prevails. Although the Lancashire Association in their answers to our questions made the strong representation, . . . it was not substantiated by any evidence of general hardship.*

But this is not a question in which the public is directly concerned; because, theoretically at least, it is the owner of the mineral subject to a way-leave who pays the way-leave charges; in other words, he gets a lordship less by the amount paid as way-leave. This was contested by some witnesses, who gave instances where it was not the case, but argument of this kind is futile unless one can exactly appraise the influence of the state of trade, and the position and necessities of the lessee at the several times at which the various leaseholds were taken, as well as the relative values of the several properties. No lessee, if he be a free agent, will give for mineral subject to a way-leave a lordship equal to what he pays for similar mineral not subject to a way-leave. If he be a free agent, but that is just what in many cases he is not, may be the retort. Well, who put him in bondage? It is either his own doing or the result of circumstances which have been too strong for him, and if so there must be some good reason of public policy for inducing the legislature to interfere to screen him from the results of his own acts or misfortunes, and this is exactly what is awanting. At the same time not a little might be said in favour of giving the proprietor, who has no outlet for his minerals except over the land of his neighbour, some relief from his disadvantage. It is said that the power to charge way-leave is merely the result of geographical position, which is part of the value of the estate. But unless a way-leave were really in existence the probability of such being ultimately exigible would rarely be taken into account in a purchase. It is often merely the accidental position of a public railway, or other means of transit on one or other side of a boundary which enables the one proprietor to claim a way-leave, and at first sight one's sense of fairness receives a kind of shock by the customary payment being so much beyond the damage to the receiver of it. Way-leaves, too, most frequently act to the disadvantage of small proprietors in favour of larger.

In the case of underground way-leaves, confined to a charge on mineral conveyed through the workings of an adjoining proprietor, the granter has generally a substantial claim on the ground alike of an easement, and

* Final Report, page 18.

of actual damage to himself. When a number of small proprietors, whose lands severally are each too small to repay a winning, combine and let to one lessee, the owner who has the shafts on his property has a certain disadvantage in damage and permanent disfigurement of his estate, and to some extent, it may be, delay in working out his mineral, but against that may fairly be placed the advantage of having control of the shafts till his mineral is worked. With a property sufficient in extent to repay a winning for itself, then, till the mineral is exhausted, the granting his tenant the right to work from other lands defers the income from his own, a substantial loss for which he is justly entitled to compensation by way-leave. Here a tonnage rate is in exact correspondence with the conditions. With underground way-leaves too, when the quantity of mineral to be worked under way-leave would justify a separate winning, a proportion should fall upon the tenant, for he saves the cost of another sinking and the erection of another fitting.

It was urged in evidence that the shaft and underground ways by which the foreign mineral is worked, are made by the lessee at his own expense, and that the landlord has no right to a way-leave, at least in the case where his own mineral is exhausted; but there remains the fact that the lessee is supposed to have repaid himself for his capital outlay by working the proprietor's own coal, and cannot fairly claim the right to recoup himself a second time. In many cases, too, the continuance of a working pit on the lands is disadvantageous both for the amenity of the estate and on æsthetic considerations, largely sentimental considerations no doubt, but nevertheless possessing a value in hard cash.

It appears that on the Continent generally there exists a right to take land compulsorily for carrying minerals, after enquiry by a Government department, on payment for ground occupied of full compensation, which in some cases means double the ordinary value of the land. This power does not exist in the United States, but there, compulsory powers to acquire land for a railway are much more easily and cheaply obtained. It is not necessary to prove public necessity: that is the promoter's concern. In the words of Mr. Carnegie:—"Any five men can organize a railway company, obtain a charter from the State for eight shillings, and go ahead. This charter gives them the right to condemn property, paying full value therefor, as assessed by the viewers (valuators)."*

The conclusion of the Commission is:—

We think that all applications for relief in such cases ought to be made to a judicial tribunal, which might be trusted to have a due regard to the existing rights

* Third Report, page 12, question 14,333.

of the owners of property over or through which passage for minerals is required, the usual charges for way-leave prevailing at the time in the district if not unreasonable, and the relative and respective rights of proprietors and lessees of the mineral property requiring way-leave. . . . We may add that we think that if such a remedy as we have suggested were open to persons who conceived themselves to be aggrieved by the unreasonable refusal of facilities for the passage of minerals, difficulties would be readily arranged by private agreement, and that only in very rare instances, if ever, would it be necessary to have recourse to compulsory proceedings.*

Severance of surface and mineral ownership has caused no little friction during the last few years. The decisions of the Law Courts have established the principle that the surface-owner is presumed to have the right of support until it is shown that his titles do not give him it. In giving judgment in the case White *v.* Dixon, Lord Blackburn said, "There is no controversy now, as to what is the law, both of England and Scotland, as to the ordinary right of support." . . . Further he says, "It is in every case a question of construction of deeds . . . to ascertain whether the proprietors of the surface have accepted them under a contract to give up the support, but I think the burthen is on those who say there is such a contract to show that there is an intention to that effect appearing on the face of the titles." This implies that the surface-owner can prevent the mineral owner so working his mines as to lower the surface even on paying compensation for damage done, and this in many cases gives him the power to render the property of the mineral proprietor valueless. Lord Blackburn thought that seeing stoop-and-room was the invariable method of working of that day, the stoops were left with the intention of supporting the surface permanently; but there is doubt approaching certainty that such was not the case in ordinary workings. The principal intention of stoop-and-room was undoubtedly to preserve the roads in the workings, and the stoops were not sufficient to maintain the level of the surface permanently—a fact that could scarcely have escaped observation. The extraction of the stoops was a later improvement in mining.

While this case did not seem to establish the rule it called attention to the law on the point, and surface-owners have naturally taken advantage of their position to get a share of the value of the coal. It has, in many cases, pressed heavily upon lessees also who were under onerous obligations to the lessor, and had sunk their capital in mines which they afterwards found they were at liberty to work only by methods that were impracticable in the circumstances. The case has been met in many instances by a payment to the surface-owner for the right to lower the surface.

* Final Report, page 21.

The report says on this point :—

We think that where the surface belongs to one person and the subjacent minerals to another, and the surface-owner having the right of support claims an injunction on the ground of threatened injury to his property, the court ought to be empowered to exercise a discretion somewhat larger than that which it appears to possess at present. Where the injury is likely to be trifling, as in the case of waste land, or capable of being repaired, as in the case of agricultural land, and, generally, where the court may be of opinion that the interests of the surface-owner may be adequately protected without enforcing his extreme rights, we think the court should be authorized to permit the mine-owner to go on with his mining operations upon terms which would ensure to the surface-owner ready information as to the progress of the workings and ample security for the payment of compensation.*

Unfortunately this appears to put the obligation to settle with the surface-owner upon the lessee, when in equity it ought to fall upon the lessor who has let minerals found unworkable owing to his limited ownership.

In the case of settled estates in England, difficulties have arisen through the limited powers of tenants for life, in the matter of duration of leases, and inability of such owners and trustees to grant concessions binding on their successors in the estate. Suggestions are made to extend the powers of tenants for life both as to granting leases and binding their successors by concessions modifying leases and dealing with shorts. Such difficulties do not materially affect Scotland, where the powers of proprietors of entailed estates appear to be extensive enough for their needs in the matter of leasing.

The most difficult and perhaps the most important question remitted to the Commission is that of the economic operation of the royalty system; and a large part of the report is devoted to its elucidation. In treating of land many economists hold that rent does not enter into the cost of the produce of a farm, because the prices obtained must be such as will repay the cost of production on the poorest land under cultivation free of rent; and conversely, the price obtained will draw the line between cultivable and non-cultivable land. Consequently rent is what is paid for the superior advantages of rent-paying land due to nearness to markets, natural productiveness of the soil, and ease in cultivation. Similarly, rent or royalty of minerals is the equivalent of superior advantages of a mineral field in geographical position, quality of produce, cost of working, and an infinite number of factors affecting the price at which the mineral can be profitably placed in the market. It is not quite so simple as the case of land. As has been already shown, royalty is not an exact equivalent of agricultural rent, inasmuch as the working of mineral from an estate deteriorates its

* Final Report, page 22.

value. A proprietor, therefore, is never prepared to lease his mineral except for a valuable consideration; nor, which is the same thing, to work them himself without at least the expectation of a profit to include a royalty over and above what a lessee would consider a satisfactory return. The working of minerals also is impossible without damage to the surface by hideous rubbish-heaps, by clouds of smoke hurting vegetation, and by subsidence, with the unsightliness of swampy ground and soured crops. The owner must therefore be paid rent or royalty to induce him to let; and consequently rent or royalty of minerals must enter to some extent into the price thereof to the consumer. Now, the function of a royalty is to equalize, or tend to equalize, the worst and best mines in competition in the open market. A perfect royalty system would exactly counterbalance the advantages of the better mines, and put all on an equality in competition; inasmuch as it would be an exact money equivalent of these advantages. Needless to say, this is unattainable; for, apart from the physical uncertainties of a mineral field and the complicated nature of the problem, the means of accurate judgment are not generally available till long after the royalty has been fixed. But its action, if necessarily imperfect, is in the main beneficial in preventing a monopoly with all its evils in the hands of the owners of the best mines, for many of the poorer mines could not be worked at all in the absence of all royalties.

The extent that royalty enters into price will, by parity of argument with the case of rent of land, be the royalty paid by the poorest mines, being the lowest amount that will induce a proprietor to let his minerals. The price at which a mine-owner will sell the produce of his mine is not determined merely by what will pay, but what the law of supply and demand enables him to obtain from the consumer; and the effect of abolishing royalties, so far as the consumer is concerned, would appear theoretically to be a lowering of price to the extent of the smallest royalty, inasmuch as that would maintain the relative position in competition of the mines at work. Given that the demand is just equal to the production of the mines, each at its maximum output, there would be no inducement to lower prices even to that extent, but the moment one mine-owner found it necessary or desired to draw a larger share of the trade the price would begin to fall. The effect might not, and probably would not, be immediate in brisk times or in face of a rising market; but it must ultimately tend to reduce prices somewhat more than the amount of the lowest royalty; and in this way abolition of royalties would almost certainly lead to the opening of poorer mines, or the re-opening of those abandoned as unworkable under royalty, and more mineral would be produced than

could be profitably disposed of. Then would follow what we call depression of trade, with the certain effect of inducing the owner of the better mines who had obtained relief by abolition of royalties to a much greater extent than the poorer, to lower prices to command trade below the point at which the latter could compete and compel their abandonment. As the collieries in existence could easily produce more than they do, the inducement to do so being increased by greater profits—as he that gets much seeks to get more—the ultimate effect would probably be to crush out some of the mines now paying the minimum royalty, and so raise the dividing-line between workable and unworkable, and making the fall of price at first somewhat more than equal to the present lowest royalty. This might be only temporary, or be modified in the event of combination of the richer mines to command the market and create a monopoly, but the great volume of the trade, the extent of the coal-fields and facility of transit, not to speak of the re-opening of poorer mines in face of enhanced prices, would act as a restraining force in any movement of the kind.

All this assumes that no benefit would reach the workmen through abolition. Professor Sorley, who has studied the subject carefully, and who spoke with more authority than any other witness on this aspect of the question, says:—

> My view is this: that what I have called the minimum royalty might be expected to go to reduce price, and that the remainder of the royalties charged on all mines paying above the minimum would go into the pockets of the lessees or employers.*

There is nothing left for the workmen, and the probabilities are rather in favour of the effect of abolition being to their disadvantage. For if poorer mines are driven out of the market the workmen must find employment in the better mines in producing the larger output required therefrom. But the productive capacity per workman in the richer mines would be greater simply because they are richer. Consequently fewer workmen would be required for an output to meet the demand, and the labour market being overstocked wages would fall; for it has yet to be shown that any organization whatever can permanently maintain the rate of wages in such circumstances. The matter is summed up by the Commission thus:—

> The whole coal industry would be dislocated by the stoppage of the mines least favourably situated, and the consequent loss of employment on the part of the workers in such mines. But some compensation would result from the employment of additional workers in the mines that obtained the trade. In so far as the lessees of the poorer mines were driven out of the trade, it would be through the lessees of the better mines offering coal at a price that would prevent competition; to the extent of this fall the consumer would derive an advantage, but this advantage would

* Third Report, page 164, question 18,351.

be only temporary, as it would probably be withdrawn as soon as the lessees of the better mines obtained control of the market. If the miners could obtain a share in the benefit of the reduction the advantage to them would be unequal, varying from district to district and from colliery to colliery; and in so far as obtained it would diminish the benefit to the consumer.*

The report also discusses the effect of a partial reduction of lordship on wages, with the result that the evidence is against the workmen being benefited, except by a continuation of employment or avoidance of reduction at the colliery affected; and in the case of a general reduction, limited of course by the amount of the lowest royalty, it is thought that possibly the miners might, by prompt action, intercept the whole or part of the reduction. It is difficult to see how this could be aught but temporary if it did happen in any degree.

The following table shows the average wages per annum paid to all classes of colliery workmen in the United Kingdom, France, Belgium, and Germany. The figures for this country are merely an estimate, but for the others they are accurately got from the statistics of the Government departments of mining.

	1888.			1889.			1890.		
	£	s.	d.	£	s.	d.	£	s.	d.
United Kingdom ...	49	16	0	60	6	0	71	16	0
France	45	5	10	47	18	4	53	17	7
Belgium	36	4	2	38	16	8		—	
Liége...	39	10	0	41	8	4	48	1	8
Germany, Westphalia	43	3	0	47	1	0	53	7	0
Saarbrücken ...	42	2	0	46	13	0	55	14	0

It is to be noted that the average wages are higher in the United Kingdom per workman, and that wages here appear to be more sensitive to the fluctuations of the market than on the Continent. The information conveyed by the table is not conclusive as to the condition of the miner, for the purchasing power of money may be different, but a considerable deduction may be made and still leave the British miner better off financially than his Continental brother. He has also an advantage in shorter hours of labour.

The relative proportions of the selling price of coal taken by the royalty owner and by the labourer is interesting and important in view of much that has been said in the course of the agitation. The ratio of the average royalty to the average selling price in the several coal-fields is given as follows† :—

* Final Report, page 43.

† The average royalty has been ascertained from the evidence, and the average selling price from the mineral statistics, which are admittedly only approximately correct.

Coal-field.	Average Selling Price per Ton. 1888.	Average Selling Price per Ton. 1889.	Average Royalty per Ton.	Percentage of Royalty to Selling Price. 1888.	Percentage of Royalty to Selling Price. 1889.
	s. d.	s. d.	d.		
Northumberland	4 4	5 4·7	4	7·7	6·18
Durham	4 5·3	5 1·8	5	9·38	8·09
Cumberland	4 10·8	5 9·2	6	10·2	8·67
Westmoreland	7 0	7 0	6	7·1	7·1
Lancashire—North and East ...	5 6	6 8	6	9·09	7·5
" West	5 4	6 3	6	9·37	8·0
Cheshire	6 0	7 0	6	8·3	7·14
Yorkshire—East and West ...	5 1·5	6 3	6	9·75	8·0
Staffordshire—North	6 0	6 6	5½	7·6	7·06
" South	5 4	6 5	6	9·37	7·8
Warwickshire	5 0	7 0	6	10·0	7·14
Worcester	5 0	6 5	6	10·0	7·8
Derbyshire	5 6	7 9	5	7·57	5·37
Nottinghamshire	5 0	7 0	5	8·33	5·95
Leicestershire	5 1	7 1	5	8·19	5·88
Shropshire	6 0	7 0	6	8·33	7·14
Somersetshire	7 7	8 1	6	6·6	6·18
Gloucestershire—Bristol	7 7	8 10	6	6·59	5·66
" Forest of Dean	7 7	8 10	3	3·29	2·83
Monmouthshire	5 11	7 5	6	8·45	6·75
South Wales—Glamorgan, East	5 9	6 9	6	8·69	7·40
" " West	5 10	8 3	6	8·57	6·06
Scotland—Lanarkshire, East ...	3 8	5 0	6½	14·77	10·83
" " West ...	3 10	5 0	6½	14·13	10·83
" Ayrshire	4 0	5 2	6½	13·54	10·48
" Fife	4 0	5 6	6	12·5	9·09

Unfortunately, there is no similar information showing the ratio of wages to selling price; but the following individual cases have, at least, the merit of being based on more exact information. Mr. Hewlett of the Wigan Coal and Iron Co., Limited, gave the following evidence:—

	Arley Mine. Half-year ending Dec. 31, 1880.	Arley Mine. Half-year ending Dec. 31, 1889.	Yard Mine. Half-year ending Dec. 31, 1880.	Yard Mine. Half-year ending Dec. 31, 1889.
Average selling price per ton ...	4s. 11·8d.	6s. 5·1d.	4s. 10·2d.	6s. 7·5d.
Percentage proportion of selling price—				
Underground wages	50·8	—	58·5	—
Surface wages	7·4	—	7·5	—
Total wages	58·2	54·2	66·3	56·4
Other payments	40·8	27·1	36·3	23·4
Royalty	10·9	8·4	10·8	7·9
Total cost	109·9	89·7	113·4	87·7
Balance	Loss 9·9	Gain 10·3	Loss 13·4	Gain 12·3

A comparison of these figures shows that the percentage of the selling price of coal taken by labour decreases as coal rises in price.

There appears to be a general feeling in favour of a sliding scale lordship on the basis of the selling price. The sliding scale has been introduced rather extensively in the North of England in recent years, and few of the witnesses had any objection to it although some preferred, as they put it, to know exactly what they had to pay. What has prevented its adoption much more frequently than has been done in Scotland, has been the want of a public standard to regulate the royalty. It is a very simple matter in the case of ironstone, where we have the price of pig-iron warrants published daily, but there is nothing to take the place of this in the case of coal. Some coal royalties, when iron-masters are lessees, are regulated by the price of pig-iron warrants; but there is no necessary connexion between that price and the price of coal in the market. The only available means of arriving at the average price is by an examination of the books of the lessee, who naturally has no particular liking for the operation. The result is friction, and the tenant is hampered in the conduct of his business; for many things have to be done to satisfy customers that a proprietor cannot allow to affect his royalty. What is the actual average sale price at the colliery is not by any means easy of ascertainment, and the system opens the way to fraud should anyone be so disposed. The tendency of a sliding scale is to enable the coal-master to work more regularly. It also reduces in some measure his risks, by eliminating one unknown quantity from his calculations in making his bargain, namely, the uncertainty of the fluctuations of the market. It is to be expected, therefore, that a sliding scale would be for the benefit of the lessee, for the reasons stated, and also for the lessor, as his tenant having eliminated one uncertainty could do with a smaller margin for contingencies, and thus the fixed royalty should be less than the average of the sliding scale as suggested by one member of Commission.

It was given in evidence—

That the substitution of a sliding scale for the fixed royalty has in times of depression enabled a colliery to be kept going that would otherwise have been closed; and the miners have thus benefited by the lessees being enabled to afford them continuous employment.*

On this subject Sir Lowthian Bell said:—

I should like to see a sliding scale introduced, if for no other reason than to satisfy the men. They, when bad iron trade comes, know that we, their employers, first suffer, then their wages are reduced, and even railway companies make some

* Final Report, page 41.

concession in their rates. Men therefore look upon it as a great hardship that the landowners, who are receiving, no doubt, collectively, a large sum from the minerals, do not suffer at all. But the men overlook the fact, I think, that the landlords in good times have never received any advantages.*

This aspect which the fixed royalty assumes to the miner in times of depression is largely responsible for the agitation which arose and led to the enquiry; and if a sliding scale would remove this imaginary injustice, its extensive adoption is well worth a trial. At the same time the benefit to be derived would not counterbalance the disadvantage attending legislation for such a purpose. The witnesses most strongly in favour of a sliding scale would have none of it by such means. It would be the equivalent of payment in kind—the earliest form of rent—as it is now the device used in leases as a safeguard in the event of the unexpected discovery of mineral of uncertain value.

The effect of royalties upon foreign competition has been much discussed in recent years, and an impression widely prevails that this country is heavily handicapped by the royalties paid. If, as already argued, only the minimum royalty enters into the price, then the comparison so far as affecting foreign competition is between the minimum royalty here and with our competitors.

The minimum royalties on coal are:—

	Per Ton.		Per Ton.
United Kingdom	2½d.	South Wales and Yorkshire	4d.
Scotland, West	3d.	Westphalia	1¾d.
" East	4d.	Belgium ... ... under	1½d.
Northumberland and Durham	4d.	France	nil.

In these relative figures we have, then, our apparent disadvantage as compared with our neighbours across the Channel. How insignificant its effect is shown by the following tables, which give, between 1880 and 1891, the percentage of increase in output and exportation in the United Kingdom, Germany, France, and Belguim; and the increase of exportation of coal to these countries:—

TABLE SHOWING OUTPUT OF COAL IN 1880 AND 1891.

	1880.	1891.	Increase.	Average Increase per Annum.
	Tons.	Tons.	Tons.	Per Cent.
United Kingdom ...	146,818,622	185,479,126	38,660,504	2·14
France	19,361,564	26,024,893	6,663,329	2·72
Belgium	16,886,698	19,675,644	2,788,946	1·40
Germany	46,973,600	73,715,653	26,742,053	4·18

* First Report, page 46, question 1,049.

TABLE SHOWING EXPORTS OF COAL.

	1880.	1891.	Increase.	Average Increase per Annum.
	Tons.	Tons.	Tons.	Per Cent.
United Kingdom ...	23,628,000	38,226,000	14,598,000	4·92
France	603,000	941,000	338,000	4·54*
Belgium	4,525,000	4,851,000	326,000	0·71
Germany	7,236,450	9,145,187	1,908,737	2·37

TABLE SHOWING EXPORTS OF COAL FROM UNITED KINGDOM.

	1880.	1891.	Increase.	Average Increase per Annum.
	Tons.	Tons.	Tons.	Per Cent.
France	3,715,762	5,258,346	1,542,584	3·21
Belgium	280,015	607,779	327,764	8·06
Germany	2,241,064	4,171,993	1,930,929	6·41
Russia	1,504,000	1,502,000	—	—
Sweden and Norway ...	1,317,000	2,439,000	1,122,000	—
Italy	1,535,000	3,551,000	2,016,000	—
Denmark	864,000	1,437,000	573,000	—
Holland	498,000	776,000	278,000	—
Portugal, Azores, and Madeira	339,000	624,000	285,000	—
Spain and Canaries ...	900,000	1,982,000	1,082,000	—
Turkey	289,000	393,000	104,000	—
Egypt	652,000	1,578,000	926,000	—
Brazil	359,000	798,000	439,000	—
Gibraltar and Malta ...	697,000	826,000	129,000	—
British East Indies ...	1,020,000	1,233,000	213,000	—
Other countries ...	2,509,000	3,905,000	1,396,000	—
Coal shipped for steamers in foreign trade..	4,926,000	8,536,000	3,610,000	—

From these tables it will be seen that since 1880, our exports of coal have increased largely to every European country except Russia. The total exports have increased in a greater ratio than the total production, and the exports to France, Belgium, and Germany (our chief competitors) have also increased at a more rapid rate than the respective outputs of these countries, as well as more rapidly than our own output. These statistics prove more conclusively than any abstract argument can do that under private ownership of minerals and royalties we can more than hold our own in foreign competition.

In this connexion a most instructive table showing variations in freight per ton during three years ending June, 1890, from the Tyne and

* This shows too favourably for France as its exports are small comparatively and fluctuate very much. In 1888 the exports were only 629,000 tons.

South Wales to various ports is given, from which the following is extracted:—

Destination.	From Tyne. s.	d.		s.	d.	From South Wales. s.	d.		s.	d.
Rouen ...	5	9	to	7	0	4	7½	to	8	6
Havre ...	4	6	„	5	6	4	3	„	7	0
Hamburg	4	6	„	5	6	4	6	„	8	0
Barcelona	10	0	„	11	6	11	0	„	15	0
Odessa ...	7	6	„	9	6	7	0	„	11	0
Cronstadt	4	3	„	6	0	5	0	„	12	6
Bombay	14	0	„	23	0	14	0	„	27	0
Alexandria	8	0	„	11	0	7	9	„	12	3
Valparaiso	15	0	„	35	0	—		„	—	

In the face of such variations, the lordship takes an insignificant place, as affecting our ability to compete on the Continent for the coal trade of these countries themselves. In competition with these countries for outside markets these do not apply.

The economic effect of royalties upon the iron trade would appear to be of even less importance, if that be possible, than in the case of coal. The production of iron ore in Spain is an object lesson for those who advocate State ownership and abolition of royalties, and shows how difficult it would be to get rid of royalties. The ore belongs to concessionaires, who pay nothing to the State, and yet the royalties paid by those who work the ore are practically the same as are paid in Cumberland under private ownership. In the face of the very high tariff imposed upon the importation of manufactured iron into so many countries it is evident that the sum paid in royalties in the United Kingdom is comparatively unimportant. And that is not all, as the policy of many foreign countries is to prevent the importation of manufactured goods entirely, and a decreased cost here which allowed of profitable exportation of manufactured iron under existing tariffs would simply be met by an enchanced import duty. In Germany steel rails are subject to a duty of 20s. a ton, and in America pig iron pays a duty of 28s. a ton, and steel ingots 37s. 6d. a ton.

Those who gave evidence before the Commission were practically unanimous in the opinion that royalties had not retarded the development of the minerals of the country, and the statistics of output already given render the opposite view quite untenable.

The mining industry has suffered from too rapid development and over-production since 1874-75, and no part of the country suffered more severely from this than the West of Scotland.

Looking to the estimated coal resources of the country, one cannot help fearing that the development has been all too rapid, and wondering what will happen to the nation when its fuel is exhausted. Unless some new and much less wasteful means of utilizing the energy stored up in coal be discovered, and that speedily, the next generation even may begin to feel that coal is becoming scarcer and dearer.

The following is a summary of the conclusions of the Commission:—

I.—We estimate that the amount paid as royalties on coal, ironstone, iron-ore, and other metals worked in the United Kingdom in the year 1889, was £4,665,043; and that the charge for way-leaves for the same year was about £216,000.

II.—We are of opinion that the system of royalties has not interfered with the general development of the mineral resources of the United Kingdom, or with the export trade in coal with foreign countries.

III.—We do not consider that the "terms and conditions under which these payments are made" are, generally speaking, such as to require interference by legislation, but we recommend that some remedy should be provided for cases in which a lessee may be prevented, by causes beyond his own control, from working the minerals he has taken, and also for cases of certain restrictions upon the assignment and surrender of mineral leases.

IV.—We are of opinion that, where the surface belongs to one person and the subjacent minerals to another, greater facilities should be provided for the working of the minerals.

V.—We are of opinion that greater facilities should be afforded to tenants for life of settled estates in dealing with mineral property.

VI.—We think that facilities for granting mineral leases for longer terms should be given to corporations and public bodies which do not already possess sufficient powers in that respect.

VII.—We recommend for the favourable consideration of Parliament any measure which may be introduced, with the concurrence of all parties concerned, for dealing with mineral leases in Cornwall and Devonshire, such as the bill which was introduced into the House of Commons by Sir John St. Aubyn in 1886.

VIII.—We consider that your Majesty's Commissioners of Woods and Forests have dealt with the Crown rights to gold in Wales as liberally as was consistent with their duty.

IX.—We are of opinion that some measures should be taken to prevent the serious obstacles to the development of the minerals in Ireland, likely to arise from the multiplication of small proprietary rights resulting from recent land legislation.

X.—As regards way-leaves, we are of opinion that owners of mineral property, unreasonably debarred from obtaining access to the nearest or most convenient public railway, canal, or port on fair terms, or from obtaining underground easements on fair terms, ought not to be left without remedy, and we have made certain suggestions with that object.

XI.—We suggest that the Department of Mines in the Home Office might be re-organized and extended, with such additional statutory powers as may be necessary for the purpose of collecting and publishing accurate information with regard to mines and minerals.*

* Final Report, page 79

These conclusions of the Commission on the points most discussed are very much what was anticipated by those familiar with the leasing and working of mines. This paper does not enter into every question discussed by the report. Several sections are not referred to, as being purely of local interest or so complicated that to have attempted to consider them would have expanded the paper beyond reasonable bounds. Metalliferous mining of Cornwall and Devon, the minerals of Ireland and the effect of recent Land Acts thereupon, and the mining legislation of foreign countries are all passed over as beyond the scope of the paper. The last-mentioned item alone would afford material for another paper.

Probably no one expected that a report would be issued over the signatures of all the members, and one wonders whether the weight of evidence or the skill of the draughtsman contributed most to the result. Evidence of compromise is not absent. With men of such diverse experience and sympathies it could not be otherwise; but that to the public eye the Commission is unanimous is much, and if, apart from the valuable information collected, the result does appear somewhat unimportant, it is due rather to the nature of the enquiry and to the character of the evidence than to any fault of the Commission.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, AUGUST 5TH, 1893.

MR. J. B. SIMPSON, RETIRING PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on July 29th and that day. The Secretary also reported the proceedings of the Council of the Federated Institution of Mining Engineers.

ELECTION OF OFFICERS.

The CHAIRMAN appointed Messrs. R. A. S. Redmayne, J. D. Wilson, John Wood, W. E. Nicholson, L. Thursby, and R. Dodd as scrutineers of the balloting papers for the election of officers for the ensuing year. These gentlemen afterwards reported the result of the ballot as follows :—

PRESIDENT.

Mr. A. L. STEAVENSON, Durham.

VICE-PRESIDENTS.

Mr. T. W. BENSON, 11, Newgate Street, Newcastle-upon-Tyne.
Mr. C. BERKLEY, Marley Hill, Swalwell, R.S.O., Co. Durham.
Mr. T. DOUGLAS, The Garth, Darlington.
Mr. W. F. HALL, Haswell Colliery, Haswell, *via* Sunderland.
Mr. J. L. HEDLEY, 22, Hawthorn Terrace, Newcastle-upon-Tyne.
Mr. G. MAY, Harton Colliery, near South Shields.

COUNCIL.

Mr. H. ARMSTRONG, Chester-le-Street.
Mr. W. C. BLACKETT, Acorn Close, Sacriston, Durham.
Mr. V. W. CORBETT, Chilton Moor, Fence Houses.
Mr. T. E. FORSTER, 3, Eldon Square, Newcastle-upon-Tyne.
Mr. W. H. HEDLEY, Medomsley, R.S.O., Newcastle-upon-Tyne.
Mr. T. HEPPELL, Leafield House, Chester-le-Street.
Mr. H. LAWRENCE, Grange Iron Works, Durham.
Mr. C. C. LEACH, Seghill Colliery, Northumberland.

Mr. T. Lishman, Hetton Colliery, Hetton-le-Hole, R.S.O.
Mr. H. Palmer, East Howle Colliery, near Ferryhill.
Mr. M. W. Parrington, Wearmouth Colliery, Sunderland.
Mr. A. M. Potter, Riding Mill-upon-Tyne.
Mr. R. Robinson, Howlish Hall, near Bishop Auckland.
Mr. T. O. Robson, Chowdene Cottage, Gateshead-upon-Tyne.
Mr. T. H. M. Stratton, Cramlington House, Northumberland.
Mr. S. Tate, Trimdon Grange Colliery, Co. Durham.
Mr. R. L. Weeks, Willington, Co. Durham.
Mr. W. O. Wood, South Hetton, Sunderland.

Ex-Officio

Past-Presidents.
Sir George Elliot, Bart., 1, Park Street, Park Lane, London, W.
Lord Armstrong, C.B., Cragside, Rothbury.
Mr. Lindsay Wood, The Hermitage, Chester-le-Street.
Mr. G. B. Forster, 3, Eldon Square, Newcastle-upon-Tyne.
Mr. John Daglish, Rothley Lake, Cambo, R.S.O., Northumberland.
Sir Lowthian Bell, Bart., Rounton Grange, Northallerton.
Mr. Wm. Cochrane, Grainger Street West, Newcastle-upon-Tyne.
Mr. J. B. Simpson, Hedgefield House, Blaydon-upon-Tyne.

Retiring Vice-President.
Mr. W. Armstrong, Pelaw House, Chester-le-Street.

The Chairman said he regretted very much that Mr. Steavenson was not present to receive his congratulations on having been elected to the Presidential chair. Mr. Steavenson ought to have been elected many years ago, but he had always declined to stand owing to his deafness. However, the Council had prevailed upon him to allow himself to be nominated on their promising to assist him in every way to overcome his defect. Mr. Steavenson, his successor, was well known to all; he had contributed some very valuable papers on mining and ventilation, and he had done very much to enhance the prosperity of the Institute.

Mr. G. B. Forster moved a vote of thanks to Mr. J. B. Simpson on his retiring from the office of President, but regretted that they should lose him. They would all agree that Mr. Simpson had conducted the affairs of the Institute in an able and energetic manner during his term of office. The Institute had taken a higher place now and during the past few years than it had ever occupied before. This was shown by its connexion with the Federated Institution of Mining Engineers in comparison with the other Institutes. He believed a very large number of members were joining this Institute so that they might become members of the Federated Institution of Mining Engineers, and in choosing this Institute they showed that they considered it to be the best. They were all sorry to lose him, although he quite endorsed what Mr. Simpson had

said about his successor (Mr. Steavenson). He begged to propose that their most cordial thanks be given to the retiring President (Mr. Simpson), and also to the retiring Vice-Presidents and Council.

Mr. J. G. WEEKS desired to echo Mr. Forster's remarks. While they were sorry to lose Mr. Simpson from the Presidential chair, yet he had some pleasure in thinking they were releasing him from what had been a strain —though a pleasurable one—upon his time and attention. He begged to second the motion.

The vote of thanks was heartily adopted.

Mr. J. B. SIMPSON replying, thanked Mr. G. B. Forster and Mr. J. G. Weeks for the flattering manner in which they had proposed the vote of thanks and also the members for its cordial adoption. He must further thank the Council and members for the kind manner in which they had supported him during his term of office. He could only say it had been a great pleasure to him to be President of the Institute, but he was afraid he had not done his duty as he might, though what he had failed in doing was from want of knowing how to do better. He could only say his love for the Institute would not abate when he left the Presidential chair, and he hoped he would be able to assist in its maintaining its position in the future.

Mr. W. C. BLACKETT moved, and Mr. J. B. SIMPSON seconded, a resolution thanking the scrutineers for their services, which was adopted.

The SECRETARY read the annual reports of the Council and Finance Committee as follows :—

ANNUAL REPORT OF THE COUNCIL.

The following table exhibits the progress of the number of the membership during the two past years :—

	1891.	August 1st. 1892.	1893.
Honorary Members	24	24	25
Members	535	545	565
Associate Members	29	35	47
Associates	28	34	47
Students	36	35	34
Subscribing Collieries	18	18	22
Totals	670	691	740

Ninety-eight members of all classes have joined the Institute during the year, and after allowing for the losses of members through death, etc., there remains a net increase of 49 members. While congratulating the members upon the increasing prosperity of the Institute, the Council would especially ask them at all times to promote its claims and advantages, and to extend its membership.

The connexion with the Federated Institution of Mining Engineers has now existed for four years, and the character of the papers communicated at its well-attended meetings proves that its success is now assured. The Mining Institute of Scotland has now become federated, and it is hoped that the remaining non-federated mining and metallurgical institutes may join at early dates.

The library has been maintained in an efficient condition during the year. The additions by donations, exchange, and purchase have been :—

Bound volumes	260	
Pamphlets, reports, etc.	234	
A total of	494	titles.

And there are now at least 6,401 volumes and 1,022 unbound pamphlets in the library.

Mr. Thomas Dacres has presented two MS. volumes of sections of Borings and Sinkings, and the Council have pleasure in recording the thanks of the Institute to him for these valuable records.

The sets of some of the Transactions of Societies, etc., in the library are incomplete owing to loss of volumes or parts, and it is urgently desired that members will return any volumes, etc., in their possession to the librarian.*

Members could also render useful service to the profession, by presentations of books, reports, plans, etc., to the Institute, where they would be preserved in the library, and be available for reference.

The report of the committee on mechanical ventilators is being completed, and the Council trust that it will be shortly issued to the members.

During the course of the year, it was deemed desirable to dissolve the then existing explosives committee, and a new committee was appointed to continue the investigations and to report upon the so-called "flameless explosives." The committee anticipate that they will be able to issue a preliminary report of their proceedings during the course of the year.

* See list in Annual Report of the Council for 1892.

The fifth volume of the Borings and Sinkings is now approaching completion, and the Council trust that the concluding volumes will be issued shortly.

The Institute has again been placed on the list of corresponding societies of the British Association, and Prof. J. H. Merivale has been appointed to act as delegate at the ensuing meeting at Nottingham.

The papers communicated to the Institute have been :—

"Use of Cement in Shaft-sinking." By Mr. Bennett H. Brough.

"Observations on Fans of Different Types working on the same Upcast Shaft." By the Rev. G. M. Capell.

"Manometric Efficiency of Fans." By the Rev. G. M. Capell.

"The Choice of Coarse and Fine-crushing Machinery and Processes of Ore Treatment." By Mr. A. G. Charleton.

"Steam Boilers with Forced Blast: the Perret System for Burning Dust and Rejected Fuels; with notes on Testing Boilers." By Mr. Bryan Donkin, Jun.

"The Electric Transmission of Power and its Analogies in Hydraulics." By Prof. Wm. Garnett.

"Notes on the Occurrence of Manganese Ore near the Arenigs, Merionethshire." By Mr. Edward Halse.

"Notes on the Occurrence of Manganese Ore near Mulegé, Baja California, Mexico." By Mr. Edward Halse.

"The Gold-bearing Veins of the Organos District, Tolima, U.S. Colombia." By Mr. Edward Halse.

"The Education of Mining Engineers." By Prof. J. H. Merivale.

"The Ordnance Maps." By Prof. J. H. Merivale.

"Joseph Moore's Hydraulic Pumping Arrangement." By Mr. R. T. Moore.

"The Geology and Coal-deposits of Natal." By Mr. R. A. S. Redmayne.

"Gold-mining in Brazil." By Mr. E. M. Touzeau.

"Queensland Coal-mining; and the Method adopted to Overcome an Underground Fire." By Mr. E. S. Wight.

"The Coad Electric Miner's Lamp." By Mr. Henry White.

The unfortunate fire in the buildings of the Literary and Philosophical Society resulted in no damage to the premises of this Institute, which so closely adjoins.

An agreement has been sealed with the North Eastern Railway Company for the use of an entrance from Orchard Street, and the occupation of a broad passage adjoining the basement of the Wood Memorial Hall.

FINANCE REPORT.

The ordinary income for the year 1892-93 amounted to £1,811 14s. 3d., being an increase over the ordinary income of the previous year of £83 18s. 5d.

The total receipts from subscriptions and arrears (excluding sums paid in advance) amounted to £1,460 11s. 0d., an increase of £74 19s. 0d. over the preceding year.

The total amount of subscriptions now in arrear (including those for the year 1892-93) is £220 10s. 0d., which, it is expected, will be fully paid. The sum of £264 12s. 0d., extending over nine years, has been struck off during the year as irrecoverable arrears.

The total expenditure amounted to £1,732 15s. 6d., a decrease of £165 2s. 9d. on the previous year, but that year included exceptional payments on account of cleaning the Wood Memorial Hall, and the expenditure of the Explosives Committee. An increase of £210 11s. 0d. in the subscriptions to the Federated Institution is caused by the increased number of members, and the special call made to meet the deficiency on the first three years' working of that Institution.

The CHAIRMAN, in proposing the adoption of the Annual Report, Finance Report, and Accounts, referred with satisfaction to the gradually increasing number of members. They had now 740 members, and he sincerely hoped that in the course of time they would rise to the number of 971 members, which they had in 1877. They would all be aware that, after that period, the North-East Coast Institution of Engineers and Shipbuilders was commeneed, and took away a considerable number of the members of this Institute, but he hoped that as time went on they might even reach the position of having 1,000 members. Another point he might mention was the satisfactory progress made by the Federated Institution of Mining Engineers; since the last General Meeting the Mining Institute of Scotland had become Federated, and it was hoped that the remaining institutes in the country would follow that example, and that there would then be one vast society—an Imperial Institution of Mining Engineers. It would be noticed that the Flameless Explosives Committee were still proceeding with their investigations; so far the committee had done very good work, but they still required more money to

continue their experiments, and the Council had to-day proposed that they should have a grant of £100 for this purpose. It would be noticed that a large amount of arrears had been written off as irrecoverable, but it must not be concluded that this was for the past year only, it represented the accumulations of nine years; the Council had, however, made such arrangements as would, it was hoped, obviate this in future, and the question of arrears would be more closely followed up. The increase of £210 11s. 0d. in the payments to the Federated Institution of Mining Engineers was caused by increased number of members, and by a special call to meet the balance of the first three years' expenditure. It was estimated that 15s. per member would meet all requirements, and it was found that the expenditure amounted to about 16s. per member, but it was hoped that after the end of the current year a call of 15s. per head would be sufficient. The Council had thought it advisable to appoint a committee to look into the question of their expenditure, with a view to seeing if it could be reduced, as it was thought that the expenditure bore rather a large proportion to their income. He begged to move the adoption of the reports and accounts.

Mr. Thomas Douglas expressed his pleasure in seconding the adoption of the reports. It occurred to him that at a meeting of this kind it was well to mention a source of income which they might tap to a greater extent—he referred to the amounts subscribed by colliery proprietors to the Institute. It appeared that such subscriptions did not amount to £100 a year, which was a very small sum when they remembered the large benefit that must accrue to the colliery proprietors from the information laid before them by the various gentlemen well calculated to give it. The Explosives Committee, for instance, were making experiments which would prove of immense value to colliery proprietors, and he thought they might fairly impress upon them that they should support an institution such as this which afforded information of such value to themselves. He mentioned this question so that the agents who were present might induce their respective proprietors to support the Institute.

The reports were adopted.

DR. THE TREASURER IN ACCOUNT WITH THE NORTH OF ENGLAND
FOR THE YEAR ENDING

			£ s. d.	£ s. d.
July 23, 1892.				
To Balance at Bankers			448 14 2	
" " in hand			36 18 4	
				485 12 6
" Dividend of 3¾ per cent. on 134 Shares of £20 each in the Institute and Coal Trade Chambers Co., Ltd., for the half-year ending December, 1892			100 10 0	
" " 3¾ for half-year ending June, 1893 ...			100 10 0	
" Interest on Investments with the River Tyne Commissioners			53 12 6	
				254 12 6
To SUBSCRIPTIONS FOR 1892-93 AS FOLLOWS:—				
431 Members	@ £2 2s.		905 2 0	
26 Associate Members	@ £2 2s.		54 12 0	
28 Associates	@ £1 1s.		29 8 0	
21 Students	@ £1 1s.		22 1 0	
56 New Members	@ £2 2s.		117 12 0	
14 " Associate Members	@ £2 2s.		29 8 0	
16 " Associates	@ £1 1s.		16 16 0	
5 " Students	@ £1 1s.		5 5 0	
			1,180 4 0	
To SUBSCRIBING COLLIERIES, VIZ.:—				
Ashington Coal Company		£2 2 0		
Birtley Iron Company		6 6 0		
Bridgewater Trustees		6 6 0		
Marquis of Bute		10 10 0		
Earl of Durham		10 10 0		
Haswell Coal Company		4 4 0		
Hetton Coal Company		10 10 0		
Hutton Henry Coal Company		2 2 0		
Marquess of Londonderry		10 10 0		
North Brancepeth Coal Company ...		2 2 0		
Owners of North Hetton Colliery ...		6 6 0		
Ryhope Coal Company		4 4 0		
Seghill Coal Company		2 2 0		
South Hetton Coal Company		4 4 0		
Stella Coal Company		2 2 0		
Owners of Throckley Colliery		2 2 0		
Victoria Garesfield		2 2 0		
Wearmouth Colliery		4 4 0		
			92 8 0	
" 1 NEW SUBSCRIBING COLLIERY—				
Butterknowle Coal Company		2 2 0		
			2 2 0	
			1,274 14 0	
Less—Subscriptions for current year paid in advance last year			23 2 0	
			1,251 12 0	
To Arrears			208 19 0	
			1,460 11 0	
" Subscriptions paid in advance during current year ...			53 11 0	
				1,514 2 0
" Sale of Publications				42 19 9
				£2,297 6 9

INSTITUTE OF MINING AND MECHANICAL ENGINEERS. CR.
JULY 31, 1893.

	£	s.	d.	£	s.	d.
July 22, 1893.						
By Stationery Account	157	3	9			
„ Books for Library	74	1	3			
„ Prizes for Papers	36	15	0			
„ Incidental Expenses	53	19	4			
„ Sundry Accounts	14	6	6			
„ Travelling Expenses	0	8	6			
„ Salaries	150	0	0			
„ Clerks' Wages	143	12	8			
„ Reporter's Salary	14	14	0			
„ Rent	95	5	8			
„ Rates and Taxes	17	19	10			
„ Insurance	8	15	9			
„ Furnishing, Repairs, etc.	26	4	9			
„ Coals, Gas, and Water	22	6	0			
„ Postages	45	5	2			
„ General Index	15	19	6			
				876	17	8
„ Fan Committee	2	19	0			
„ Explosives Committee	85	1	1			
„ British Association Meeting—Delegate's Expenses ...	6	9	0			
				94	9	1
By Federated Institution of Mining Engineers—Subscriptions	791	15	10			
Less—Amounts repayable by Authors for Excerpts ...	30	7	1			
				761	8	9
				1,732	15	6
By Balance at Bank	468	3	8			
„ „ in hand	84	12	3			
„ Outstanding Amounts by Authors for Excerpts ...	11	15	4			
				564	11	3
				£2,297	6	9

I have examined the above account with the Books and Vouchers relating thereto, and certify that, in my opinion, it is correct.

JOHN G. BENSON,
CHARTERED ACCOUNTANT.

Newcastle-upon-Tyne,
August 4th, 1893.

Dr. **The Treasurer in Account**

	£	s.	d.	£	s.	d.
To 544 Members, 24 of whom are Life Members.						
520 520 @ £2 2s.				1,092	0	0
To 35 Associate Members, 5 of whom are Life Members.						
30 30 @ £2 2s.				63	0	0
To 34 Associates @ £1 1s.				35	14	0
To 37 Students, 1 transferred to list of Members.						
36 36 @ £1 1s.				37	16	0
To 18 Subscribing Collieries				92	8	0
To 56 New Members @ £2 2s.				117	12	0
To 14 New Associate Members @ £2 2s.				29	8	0
To 16 New Associates @ £1 1s.				16	16	0
To 5 New Students @ £1 1s.				5	5	0
To New Subscribing Collieries				6	6	0
				1,496	5	0
To Arrears, as per Balance Sheet 1891-92	470	8	0			
Deduct 6 Students transferred to Members @ £1 1s. ...	6	6	0			
	464	2	0			
Less—Struck off as irrecoverable. Arrears £206 17 0						
" " " Current year 57 15 0	264	12	0			
				199	10	0
				1,695	15	0
To Subscriptions for previous year paid by New Members				8	8	0
" Subscriptions Paid in Advance				53	11	0
				£1,757	14	0

WITH SUBSCRIPTIONS, 1892-93. CR.

			PAID. £ s. d.	UNPAID. £ s. d.
By 431 Members, paid	... ...	@ £2 2s.	905 2 0	......
By 87 „ unpaid	... ...	@ £2 2s.	......	182 14 0
By 2 „ dead	... ...	@ £2 2s.	......	4 4 0
520				
By 26 Associate Members, paid	... ...	@ £2 2s.	54 12 0	......
By 4 „ „ unpaid	... ...	@ £2 2s.	......	8 8 0
30				
By 28 Associates, paid	... ...	@ £1 1s.	29 8 0	......
By 6 „ unpaid	... ...	@ £1 1s.	......	6 6 0
34				
By 21 Students, paid	... ...	@ £1 1s.	22 1 0	......
By 15 „ unpaid	... ...	@ £1 1s.	......	15 15 0
36				
By Subscribing Collieries	... ...		92 8 0	......
By 56 New Members, paid	... ...	@ £2 2s.	117 12 0	......
By 14 New Associate Members, paid	... ...	@ £2 2s.	29 8 0	......
By 16 New Associates, paid	... ...	@ £1 1s.	16 16 0	......
By 5 New Students, paid	... ...	@ £1 1s.	5 5 0	......
By 1 New Subscribing Colliery, paid	... ...		2 2 0	......
By 1 „ „ unpaid	... ...		......	4 4 0
			1,274 14 0	221 11 0
Less struck off as irrecoverable	... ...		......	57 15 0
				163 16 0
By Arrears, paid	... ...		208 19 0	......
„ „ unpaid	... ...		......	56 14 0
By Subscriptions paid in advance	... ...		53 11 0	......
			1,537 4 0	220 10 0
				1,537 4 0
				£1,757 14 0

General Statement, July 22nd, 1893.

Liabilities.	£	s.	d.	£	s.	d.
Subscriptions paid in Advance during the year	53	11	0			
„ carried over from previous year	4	4	0			
				57	15	0
Capital				9,394	8	9
				£9,452	8	9

Assets.	£	s.	d.	£	s.	d.
Balance of Account at Bankers	468	3	8			
„ in Treasurer's hands	84	12	3			
Outstanding amounts for Authors' Excerpts ...	11	15	4			
				564	11	3
134 Shares of £20 each in the Institute and Coal Trade Chambers Co., Ltd.	......			2,680	0	0
Invested with River Tyne Commissioners ...	......			1,500	0	0
Arrears of Subscriptions	......			220	10	0
Value of 548 Bound Volumes of Transactions, @ 8s. 6d.	232	18	0			
„ 4,460 Sewn do., @ 6s.	1,338	0	0			
„ 2,421 Unbound Parts, @ 1s.	121	1	0			
„ 77 Copies of Mr. T. F. Brown's Map, @ 2s. 6d.	9	12	6			
„ 375 Copies of Index, Vols. 1-25, @ 1s.	18	15	0			
„ 849 Copies of Catalogue of Fossils, @ 2s. 6d.	106	2	6			
„ 755 Copies of Fossil Illustrations, @ 5s.	188	15	0			
„ 1,500 Copies of Borings and Sinkings (Vol. I. in Sheets) @ 1s.	75	0	0			
„ 275 Do., Vol. I., @ 2s. 6d.... ...	34	7	6			
„ 304 Do., Vol. II., @ 2s. 6d.... ...	38	0	0			
„ 317 Do., Vol. III., @ 2s. 6d.... ...	39	12	6			
„ 429 Do., Vol. IV., @ 2s. 6d.... ...	53	12	6			
„ 263 Copies of Library Catalogue, @ 1s.	13	13	0			
„ 313 Copies of French Commission Report on Explosives in parts, @ 1s. ...	15	13	0			
„ 10 Do., Bound, @ 4s.	2	0	0			
				2,287	2	6
„ Office Furniture and Fittings ...	450	0	0			
„ Books and Maps in Library	1,750	0	0			
				2,200	0	0
				£9,452	8	9

I have examined the above account with the books and vouchers relating thereto, and certify that, in my opinion, it is correct. The Share Certificates and Bonds have been produced to me.

JOHN G. BENSON,
Chartered Accountant.

Newcastle-upon-Tyne,
August 4th, 1893.

REPRESENTATIVES ON THE COUNCIL OF THE FEDERATED INSTITUTION OF MINING ENGINEERS.

The SECRETARY stated that the Council had nominated the following gentlemen for election:—

Mr. WM. ARMSTRONG Jun.
Mr. T. W. BENSON.
Mr. THOS. J. BEWICK.
Mr. WM. COCHRANE.
Mr. JNO. DAGLISH.
Mr. THOS. DOUGLAS.
Mr. T. E. FORSTER.
Mr. J. L. HEDLEY.
Mr. T. HEPPELL.
Mr. HENRY LAWRENCE.
Mr. W. LISHMAN (B.H.).
Mr. GEO. MAY.
Prof. J. H. MERIVALE.
Mr. M. W. PARRINGTON.
Mr. J. B. SIMPSON.
Mr. A. L. STEAVENSON.
Mr. T. H. M. STRATTON.
Mr. J. G. WEEKS.
Mr. W. O. WOOD.

The CHAIRMAN moved and Mr. COCHRANE seconded the motion, which was unanimously agreed to, that these gentlemen be elected as the representatives of this Institute for the ensuing year.

Mr. T. H. M. STRATTON proposed that a hearty vote of thanks be accorded to those gentlemen who had represented the Institute on the Council of the Federated Institution during the past year. Any member of this Council who proposed to devote the proper amount of time and attention to it would do so at considerable sacrifice. The meetings were held at such times and places as rendered it very difficult for the representatives from this district to attend, unless they were masters of their own time, and no doubt those members who had been struck off the list as ineligible for re-election owing to non-attendance would have been present if it were possible; and to those who had attended the thanks of the Institute were especially due. The Council had done him the honour to include his name in the list of representatives for the ensuing year, and he made these remarks fearing lest he might be deprived from attending.

Mr. JOHN SIMPSON seconded the vote of thanks, which was unanimously adopted.

Mr. WILLIAM COCHRANE said he was certain those members of the Council who had attended the meetings would be glad to feel that what they had done met with the approbation of the members. Mr. Stratton's remarks raised a point of some importance; the fact of the meetings being frequently held in the Midland Counties rendered it difficult for the members from this district to attend, but they must make an effort to do so, otherwise there would be a much more active interest and influence exerted by the representatives of the institutes which did attend, and this

Institute would be slipping away from the position and influence it had hitherto exercised as the leading Mining Institute, and as the originator of the Federated Institution of Mining Engineers.

The following gentlemen were elected, having been previously nominated:—

HONORARY MEMBER—

Professor JOHN HERMAN MERIVALE, Professor of Mining, Durham College of Science, Newcastle-upon-Tyne.

MEMBERS—

Mr. ARCHIBALD THOMAS BROWN, Mining Engineer, 372, Flinders Lane, Melbourne.

Mr. WESTGARTH FORSTER BROWN, Mining Engineer, Alston House, Parade, Cardiff.

Mr. RICHARD ECK, Mining and Mechanical Engineer, Phœnix Hotel, Beaconsfield, South Africa.

Mr. JOSEPH GOULDIE, Mining and Civil Engineer, The North-Eastern Bulfontein, Kimberley, South Africa.

Mr. JOSEPH HARGREAVES, Colliery Manager, Gwaun Cae Gurwen Collieries, Brynamman, R.S.O.

Mr. JOHN HOLT, Jun., Civil and Mining Engineer, The Hollies, Heywood, Lancashire.

Mr. EDWARD HOPPER, Engineer, c/o Messrs. Lewis & Marks, Coal Mines, Vereeneging, Transvaal.

Mr. JOHN WILSON RICHMOND LEE, Mining Engineer, Potes, Provincia de Santander, Spain.

Mr. J. B. ROBINSON, Mining Engineer, Hedley Hill Colliery, Waterhouses.

Mr. WALTER ROWLEY, Mining Engineer, 20, Park Row, Leeds.

Mr. THOMAS BIRCH FREEMAN SAM, Mine Manager, Adjah Bippo, West Coast, Africa.

Mr. JOSEPH SCOTT, Mining Surveyor, Newcastle Street, Stockton, near Newcastle, New South Wales.

ASSOCIATE MEMBER—

Mr. GEORGE THOMAS DUNCAN, Engineer and Agent, 110, Dilston Road, Newcastle-upon-Tyne.

ASSOCIATES—

Mr. EVAN COCKBURN, Back Overman, Page Bank Colliery, *via* Willington, Co. Durham.

Mr. WM. HENDERSON, Engineer, Wheatley Hill Colliery, *via* Trimdon Grange.

Mr. MOSES HOBSON, Under Manager, Shildon, *via* Darlington.

The following gentlemen were nominated for election :—

MEMBERS—

Mr. JOHN WATSON COOK, Colliery Manager, Greenfield House, Crook.

Mr. LEWIS EVANS, Mining Engineer, Coetzeestroom Estate and Gold-Mining Co., Ltd., Kaapsche Hoop, North Dekaap, Transvaal.

Mr. FRANK SIMPSON FERENS, Mechanical and Electrical Engineer, 13, Railway Arches, Westgate Road, Newcastle-upon-Tyne.

Mr. HENRY J. GIFFORD, Superintendent of the Ouro Preto Mines of Brazil, Ltd., Mines de Passagem, Ouro Preto, Brazil.

Mr. FREDERICK HALL, Mines Manager, Harrington Road, Workington.

Mr. JOHN HEDLEY, Mining Engineer, Coatham, Redcar.

Mr. JOHN CARY BAKER HENDY, Mining Engineer, Etherley, by Darlington.

Mr. FRANK T. HOWES, Assistant Colliery Manager, Singareni Collieries, Hyderabad, Deccan, India.

Mr. WILLIAM HUMBLE, Government Inspector of Collieries, Coal-fields Office, Newcastle, New South Wales.

Mr. WILLIAM HAMILTON MERRITT, Mining Engineer and Metallurgist, 485, Huron Street, Toronto, Ontario, Canada.

Captain G. NICHOLLS, H.M. Commissioner of Mines for Natal and Zululand, Pietermaritzburg, Natal.

Mr. RALPH NIXON, Lecturer on Mining to Northumberland County Council, 47, Holly Avenue, Newcastle-upon-Tyne.

Mr. JOHN SHOTTON, Assistant Engineer, Locomotive Department, Ottoman Railway Co., Smyrna, Asia Minor.

Mr. JAMES JOSEPH TONKIN, Manager of Silver-lead Smelting Works, Linares, Provincia de Jaen, Spain.

ASSOCIATE MEMBERS—

Mr. HERMAN ALEXANDER KROHN, Secretary to the Roburite Explosives Co., Ltd., 103, Cannon Street, London, E.C.

Mr. GEORGE FREDERICK MANSELL, Public Accountant and Fellow of the Institute of Secretaries, St. Mary's Chambers, Church Street, Colchester, Essex.

ASSOCIATES—

Mr. J. T. BOLAM, Overman, The View, Beamish, Chester-le-Street.

Mr. JOHN FAIRS, Under Manager, Escomb Bridge, Bishop Auckland.

STUDENT—

Mr. ALGERNON NOBLE, Mining Apprentice, Broomhill Colliery, Acklington.

Mr. C. C. LEACH read the following paper on a "Corliss-engined Fan at Seghill Colliery":—

CORLISS-ENGINED FAN AT SEGHILL COLLIERY.

By C. C. LEACH.

The ventilation at Seghill colliery was, until recently, produced by two furnaces, one placed in the yard seam and the other in the low main seam, burning 1,310 tons of coal per annum.

It was decided to erect a fan capable of doubling the volume of air then circulating in the blake and yard seams.

The calculated power of the engine to do this was 120 indicated horse-power, and a fan 35 feet in diameter running 61 revolutions per minute.

The following table contains the results of experiments, as compared with the preliminary calculations:—

TABLE I.

Name of Seam.	Depth from the Surface.	Volume of Air produced by Furnace per Minute.	Calculation of the Volume of Air produced by Fan running at 61 Revolutions per Minute.	Volume of Air per minute produced by Fan when running at 60 Revolutions per Minute in the return Air-ways.
	Feet.	Cubic Feet.	Cubic Feet.	Cubic Feet.
Blake ...	210	24,460	48,920	66,721
Yard ...	275	23,222	46,440	45,567
Low main	421	15,028	15,028	9,996
Total volume of air ...		62,710	110,388	122,284
Total horse-power in air		10·87	58·94	52·65
Indicated horse-power of engine			120·00	96·11

The above table shows that less speed and power is required to produce the desired volume of air by the fan than was calculated, but this result was expected, and is due to the openings into the shafts and airways being improved, and to the fan and engine yielding 4·78 per cent. higher useful effect than was anticipated, besides any fractional part was set against the engine.

Most fan engines are far too large for the work they are doing, and therefore have very low initial pressures on the piston, the steam being on for nearly the full stroke, but throttled down by the stop-valve to sometimes even 8 or 10 lbs. per square inch, and owing to the absence of governors the speed varies as the boiler pressures rise and fall. These large engines have a great amount of extra weight to keep moving, they require larger steam pipes, and have large radiating surfaces.

To overcome these defects and to obtain the most economical engine possible with one cylinder, the Corliss engine and a steam pressure of 100 lbs. per square inch was selected; because in the writer's opinion it is the highest pressure that can be used with advantage in an engine with one cylinder, and affords great range of economic power in this type of engine with its variable automatic cut-off.

The fan has been at work fifteen months; it is open-running, 35 feet 1 inch in diameter, the inlet is 12½ feet in diameter, and the inside width at the rim is 15½ inches. It is made of extra thick steel plates, the front plates being $\frac{3}{16}$ inch thick, the back plates ¼ inch, the back plates opposite the inlet are $\frac{7}{16}$ inch, and the vanes $\frac{3}{16}$ inch, and it weighs about 19 tons. The fan shaft is mild steel 8 feet 8 inches long between the bearings, 11½ inches in diameter, and where the fan bosses are keyed on it is 12 inches in diameter. The drift bearing (which carries two-thirds of the weight) is 10 inches in diameter and 20 inches long; the bearing in the engine-house is 8½ inches in diameter and 14 inches long. The fan and shaft were made by Messrs. Thornewill & Warham.

The engine was built by Messrs. Hick, Hargreaves, & Co., and has one horizontal high-pressure cylinder, 16 inches in diameter and 3 feet stroke, with separate end-valve chambers, separate internal cylinder-barrel of special cast-iron, sight-feed lubricator, and steam-jacketed. Both the cylinder and its covers are felted and lagged. The steam and exhaust valves are Corliss valves, worked by the Inglis and Spencer gear; there are double eccentrics and two wrist-plates for working the steam and exhaust valves independently. The wear on the trip-gear is almost inappreciable.

The engine-frame is of box-girder pattern, carrying the crank shaft with phosphor-bronze steps, and having horizontal and vertical adjustments.

The governor controls the speed automatically by varying the cut-off to the speed it is weighted for, from 0 to ¾ stroke; the weights can be added or taken off while the engine is running. By adjusting the lever-rods the

governor will allow the steam on for the whole of the stroke continuously, or just now and again as the work done requires.

The valves, each working independently, are very easily set, and almost frictionless, being handed to start the engine with a very short lever. They give the shortest possible ports to and from the cylinder, the waste spaces calculated from the drawings (including ½ inch clearance) is only 5·175 per cent. of the contents of the cylinder.

The piston rod is 3 inches in diameter and works through Cruickshank metallic packing, which is efficient—there is not a scratch on the rod. The crank pin is 4½ inches in diameter and 5 inches long.

The main bearing in the drift has three weighted piston lubricators and is supplied with solid grease. The engine-house bearing of the fan shaft has circulating lubrication. The crank pin has an oil-syphon and centrifugal lubrication.

Calculated from the result of 225 days' working, the stores used by the engine per year are as under :—

	£	s.	d.
42 gallons of cylinder oil, at 2s.	4	4	0
18 gallons of engine oil, at 1s.	0	18	0
14½ gallons of castor oil, 130 lbs., at 3½d.	1	17	11
133 lbs. of waste, at 2d.	1	2	2
16 sheets of emery cloth, at 1d.	0	1	4
Yearly cost of stores for engine	8	3	5
114 lbs. Delettrez grease for drift-bearing,* at 1s. 4d....	7	12	0
Total	£15	15	5

The engine gives neither knock nor heat on the bearings, although there is about 9 tons of push each time the steam is admitted at every speed ; with attention, it gives the engineman no trouble.

The engine and foundations are adapted for a condenser being added, if more power be required, but at present, at 40 revolutions, the engine is too big for its work.

The steam pipes are 103 feet long and 7 inches in diameter, and 14 feet of 5 inches in diameter pipes with ten right-angled bends. Other engines are supplied by the 7 inches pipes. The exhaust pipes are 9 feet long and 5 inches in diameter, with three right-angled bends. All the steam pipes are covered.

The only true test of the efficiency of an engine is the weight of steam or water required to drive it, for then the type and size of boiler and kind

* Oil did not keep the drift-bearing cool.

of coal burnt does not interfere with the result; therefore the weight of steam or water used per indicated horse-power per hour is given in Table IV.

The indicator spring was tested with weights, the indicator being screwed upside down on to the steam pipe, and heated during the test with live steam.

The indicator cards were worked out by a planimeter.

The revolutions of the engine were got by a Harding counter and divided by the time to get the revolutions per minute.

A correction of 30 was added to the anemometer revolutions per minute.

The fan drift has an area of 182 square feet, and is divided by wires into 91 squares; each measurement of the air took fifteen minutes..

There is one downcast pit (11 feet in diameter), with 4 cages; one downcast pit (8 feet in diameter), with 2 cages and steam pipes; and one upcast shaft (11 feet in diameter) clear of all obstruction.

A König water-gauge was used when running at 20 revolutions per minute; and the ordinary water-gauge for the higher speeds. The end of the water-gauge pipe in the drift was 10 feet 4 inches from the centre of the fan shaft, with the end turned towards the fan.

In testing the engine, the water used was pumped from a tank into the boiler.

The specimen indicator cards (Figs. 1, 2, 3, and 4, Plate I.) from the engine, when running at 20, 40, and 60 revolutions per minute, were taken with the mine under ordinary conditions, and at 60 revolutions with the separation-doors open, the air being measured in the drift. Another card (Fig. 5) was taken at 67 revolutions of the fan, the separation-doors being open and full steam turned on the engine for the full stroke, indicating 209·2 horse-power.

The indicator cards were taken by passing the pencil over the same cards three times during each air measurement and about every ten minutes during the steam-consumption tests, the card being changed every hour, and the averages taken.

On April 25th, 1892, the front steam-valve was disconnected and the steam turned full on the engine again; the governor kept the engine running for 5½ hours at the same speed (35 revolutions), although the steam was only admitted to the back end of the cylinder, the indicated horse-power being about the same as the previous day, with both valves at work (Fig. 6, Plate I.).

TABLE II.

Date of Experiment	April 29th, 1893.	May 11th, 1893.				May 15th, 1893.				Average of Experiments, 2 to 9.
No. of Experiment..	1.	2.	3.	4.	5.	6.	7.	8.	9.	
Condition of mine	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.
Revolutions of fan per minute	19·87	39·97	39·87	39·63	39·90	39·52	39·89	39·72	39·95	39·806
Revolutions of anemometer per minute... ...	242	448	443	446·5	454	460	458	455	461	--
Velocity of air in feet per minute	272	478	473	476·5	484	490	488	485	491	--
Volume of air in drift in cubic feet per minute	49,686	86,996	86,086	86,728	88,088	89,180	88,816	88,270	89,362	87,940
Water-gauge in drift in inches	0·29	1·18	1·133	1·12	1·108	1·06	1·06	1·06	1·06	1·09
Temperatures in air, wet bulb	—	54¼	58	52	51½	46⅜	46½	46½	46½	—
" " dry bulb	45½	62½	61½	59	58¾	47½	47¼	47⅜	47¼	—
" in drift, wet bulb	—	60	59¾	59¼	59¼	60	60⅜	59⅜	59⅜	—
" " dry bulb	60½	60	60	59½	59½	60	60½	59½	59¾	—
Boiler pressure, pounds per square inch... ...	60	99	100	100	99	99	100	99	100	—
Mean pressure of indicator-diagrams in pounds per square inch	9·04	20·26	20·565	20·28	20·224	21·09	21·00	21·17	21·21	—
Weight of an inch of water in pounds	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2
Horse-power in air...	2·27	15·49	15·36	15·305	15·81	14·89	14·83	14·74	14·92	15·105
Indicated horse-power of engine	6·463	29·08	29·44	28·86	28·97	29·86	30·08	30·19	30·42	29·612
Efficiency, per cent.	35·12	53·26	52·17	53·03	52·84	49·80	49·30	48·82	49·05	51·02

TABLE III.

Date of Experiment	May 17th, 1893.				May 25th, 1893.				Average of Experiments, 10 to 17.	May 14th, 1893.		
No. of Experiment	10.	11.	12.	13.	14.	15.	16.	17.		18.	19.	20.
Condition of mine	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	*	*	*
Revolutions of fan per minute	60·83	60·82	60·68	61·00	59·96	60·42	60·08	59·72	60·44	60·00	59·88	67
Revolutions of anemometer per minute	746	734	723	734	694	697·5	704·2	694	—	1,330	1,332	—
Velocity of air in ft. per minute	776	764	753	764	724	727·5	734·2	724	—	1,360	1,362	—
Volume of air in drift in cubic feet per minute	141,232	139,048	137,046	139,048	131,768	132,405	133,624	131,768	135,742	247,520	247,884	—
Water-gauge in drift in inches	2·46	2·47	2·46	2·48	2·42	2·44	2·50	2·46	2·46	2·14	2·14	—
Temperatures in air, wet bulb	48	48	48½	48	49½	49¼	48¼	48	—	52	52	—
" " dry bulb	48½	47½	48½	48	54½	54½	52	51½	—	55½	55½	—
" in drift, wet bulb	—	60	59½	—	58½	58½	58¼	58	—	56	56	—
" " dry bulb	—	60	59½	—	59	59	58¾	58½	—	57½	57½	—
Boiler pressure in lbs. per sq. in.	99	99	98	100	97	97	99	97	—	106	106	—
Mean pressure of indicator diagrams in pounds per sq. in.	45·34	45·04	44·87	45·02	43·428	43·468	43·880	43·203	—	71·32	72·10	86·95
Weight of an in. of water in lbs.	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	—
Horse-power in air	54·746	54·119	53·124	54·338	50·247	50·907	52·64	51·08	52·65	83·47	83·59	—
Indicated horse-power of engine	99·04	98·37	97·76	98·62	93·505	94·31	94·66	92·65	96·114	153·67	155·03	209·2
Efficiency per cent.	55·27	55·01	54·34	55·09	53·73	53·99	55·61	55·13	54·78	54·32	53·92	—

* Separation-doors open.

NOTES ON WORK DONE BY THE STANLEY HEADING-MACHINES AT HAMILTON PALACE COLLIERY.

By JAMES S. DIXON.

Owing to the circumstances of this coal-field it was considered desirable to use some other means than hand labour to more quickly drive into and open up the workings. With this object in view the Stanley heading-machine was adopted.

These machines are driven by compressed air, and as with all machines it is essential to success to have an ample supply of motive power, a few notes on this head may be of interest.

A set of air-compressors were put down, with double steam and air-cylinders, each 20 inches in diameter by 3 feet 6 inches stroke. The air-cylinders are fitted with the Walker system of valves, which form the feature of their construction. The pistons of the air-cylinders are coupled direct to those of the steam-cylinders, and are usually driven at about 18 revolutions per minute. The air is compressed to a pressure of 60 lbs. per square inch, and is received into a steel boiler, 28 feet long by 6 feet in diameter, placed in the engine-house. The air passes through about 90 feet of cast-iron pipes, 18 inches in diameter, towards the top of the pit, and by 6 inches pipes down the shaft to a second receiver, 25 feet long by 4 feet in diameter, a distance altogether of about 350 yards from the engines. From the pit-bottom it is conveyed by 6 inches pipes a distance of about 1,150 yards to a third receiver, 25 feet long by 4 feet in diameter; thence by 7 and 6 inches pipes a further distance of 235 yards, and by 400 yards of 2 inches malleable iron pipes to the machines, which are connected to this pipe by short lengths of flexible hose, 2 inches in diameter.

As before stated, the air in the first receiver in the engine-house has a pressure of 60 lbs. per square inch, and that pressure is maintained without appreciable loss in the second and third receivers. At the end of the 2 inches pipes, close to the machines, with these not working, the pressure is about $\frac{1}{2}$ lb. less, but when the machines are at work it falls to about 15 lbs., owing no doubt to the friction in the long length of 2 inches pipes.

Besides working the two heading-machines, the compressed air actuates eight pumping-engines, and one hauling-engine of the dimensions, and doing work as follows, viz.:—

Description.	Air-cylinders.		Diameter of Pump.	No. of Strokes per Minute.	Hours Worked per Day.
	Diameter.	Stroke.			
	Inches.	Inches.	Inches.		
1 Worthington pump, double ...	3	3	2	150	8
1 Tangye pump, single	4	11	3	120	20
4 " "	6	12	4	40 to 60	10 to 24
1 Cameron pump, double ...	6	6	4	40	12
1 " " ...	7	6	5	40	10
1 Hauling-engine	9	18	—	130	1½

These air-compressors have been at work night and day since December, 1888; and as they are working well within their capacity, they have given little trouble. As all the workings are below the level of the pit-bottom, and as troubles cause many depressions, the use of compressed air underground has been of great advantage irrespective of its use in the coal-cutting machines, for which it was originally introduced.

The Stanley heading-machine has already been fully described by Mr. R. Stanley* and by Mr. G. Blake Walker.† It may, however, be briefly described as consisting of a frame carried on two wheels set tandemwise, one in advance of the other. This frame carries an engine with two cylinders, and the engine-shaft is geared to the principal cutting-shaft, which passes through the centre of the frame. On the end of the principal shaft a cross-head is fixed, carrying at right angles the two arms upon which the cutters are fastened. The object to be accomplished is, by the rotation of the cross-head and arms, to cut an annular groove in the face of the heading.

The machines adopted at Hamilton Palace colliery make a cutting 5 feet in diameter. The cylinders are each 9 inches in diameter by 9 inches stroke, geared to the central cutting-shaft as 13 to 1. This shaft has a screw thread cut nearly its whole length, by which, and suitable gearing, the cutters are advanced. The arms project about 3 feet beyond the cross-head; and this length controls the extreme depth of each cut. The machine is anchored to the sides and floor to maintain it in position, and to keep the cutters against the face. When a cut the length of the arms has been made and the coal removed, the cutting motion is put out of gear and the advancing motion put into gear, by which the whole machine is propelled forward to begin anew.

The small coal made in cutting the groove, which is about 3 inches wide, is raked or shovelled back by a man placed at the side of the

* *Trans. Chesterfield Institute*, vol. xvi., page 192.

† *Trans. Fed. Inst.*, vol. i., page 124.

machine at first, and as the cross-head advances he can work in front. The centre core of solid coal generally breaks down, and is removed once or oftener during each cut; and if any remain it is taken down by picks or wedges. The actual cutting by the machine is done very rapidly as will be afterwards shown, most of the time being occupied in removing the coal and shifting and re-fixing the machines.

At Hamilton Palace colliery, the first trials were made with one machine; but it was soon found that the exhaust air was insufficient to keep the place clear of fire-damp; and a continuous blower of compressed air likewise failed, besides being a most expensive mode of ventilation. There was also difficulty from water, as the leading places dipped sufficiently and allowed it to accumulate at the face. A hole 5 feet in diameter gives no facilities for bratticing, and few for leading in pipes, loading coal and carrying on the work.

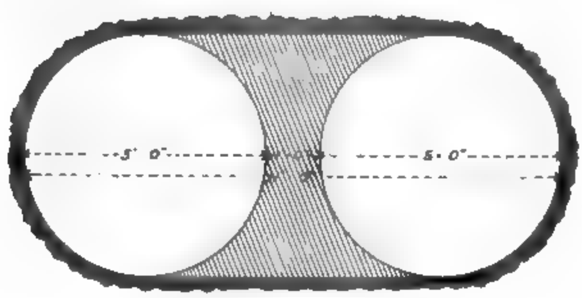


Fig. 1.

As the usual haulage roads are 11 feet wide, it was resolved to try two machines, one working immediately in front of the other. These are driven so as to leave between the drifts about 1 foot of coal, which is to some extent utilized as a bratticing for guiding the air, and is afterwards removed, leaving the roof flat with curved sides, which stand well (Fig. 1). This manner of driving gives room for ventilation, loading, and removing the coal, and following up with pumps and pipes when necessary.

The heading-machines have been at work since December, 1888, and during that time have cut about 3,000 yards of places 11 feet wide in the ell coal-seam, and about 800 yards in the splint coal-seam. The ell coal-seam is about 7 feet and the splint seam about 6½ feet in thickness, so there is ample room for the 5 feet cut. In some parts, the ell coal-seam had blaes (shale) partings from 1 to 3 inches in thickness, but these and the harder nature of the splint coal-seam, and its accompanying cannel coal, made little or no difference in the work done by the machines. In some places, where small slips intervened, either the roof or the pavement,

which are strong fakes and hard fireclay respectively, was encountered and cut through for short distances without difficulty.

After considerable experience, the plan adopted, as the most efficacious, is to drive the places in pairs, the leading places being about 100 feet apart (Fig. 2). The dip place is driven a distance of about 200 to 300

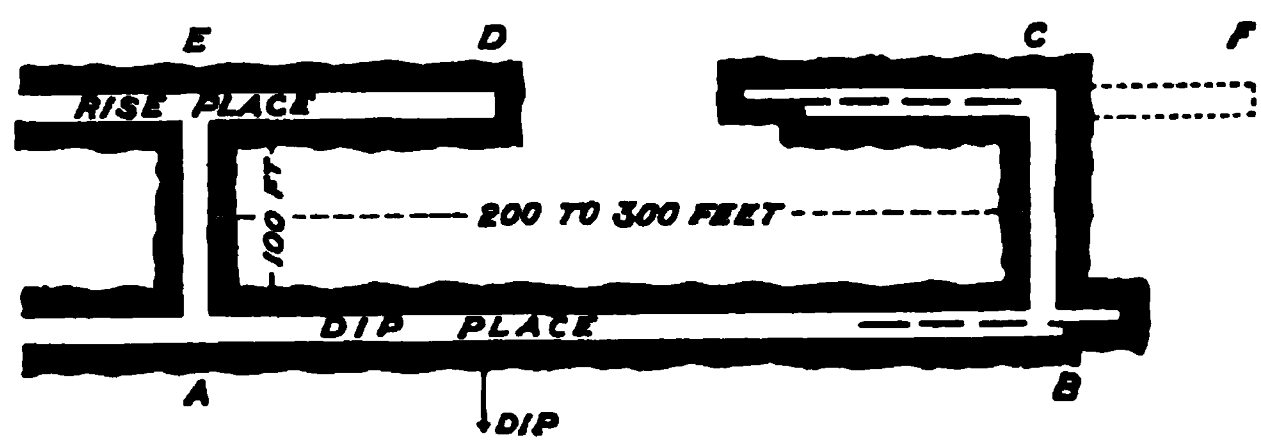


FIG. 2.

feet in advance from A to B, the cross-cut (B to C) is then made. The machines are then turned backward at C, so as to drive a place in the direction of D, and meet the rise place which had previously been driven 50 to 100 feet in advance of the former cross-cut E. When the rise place C E is holed through, the machines are drawn back to C and the rise place driven from C to F in advance (as at E to D) as far as convenient. The machines are then transferred to the face of the dip place at B, and the entire process repeated.

Under favourable circumstances, such as places going to the rise, sufficient to allow of water flowing away, distances of a length of 650 feet have been driven without cross-cuts. By the mode of driving, above described, a certain amount of progress is lost (though it was found necessary, to enable a sufficient current of air to be well up to the face), but by employing 3 or 4 machines continuous progress could be made. As the merits of any such machine can only be judged from the actual work done over a period of time, the following record was kept when a comparatively clean and continuous area of coal was being operated upon, with the following results, viz.:—

Fortnights.	Shifts Worked.	Distance Cut 5 Feet in Diam.	Distance Cut per Shift.	Amount Paid for Cutting and Filling.			Cost per Lineal Foot Cut.	
		Feet.	Feet.	£	s.	d.	s.	d.
1	23	283	12·30	35	9	9	2	6·09
2	23	270	11·74	33	3	9	2	5·50
3	24	276	11·50	31	4	6	2	3·15
4	18	212	11·77	23	8	2	2	2·50
5	19	230	12·10	20	18	0	1	9·80
6	23	284	12·34	24	19	6	1	9·10

There was a reduction of wages during the two last fortnights, hence the lessened cost.

As previously mentioned, the time occupied by the machines in cutting is comparatively small. The following is a record kept of actual work done, viz.:—

	Hours.	Mins.	Hours.	Mins.
Time at work, exclusive of meals	...	...	8	14
Cutting at the face	1	18		
Breaking down and throwing back the coals	3	43		
Shifting and re-adjusting the machines ...	3	13		
			8	14

During this time, 5 men were employed, the distance cut was 15 feet 1 inch, and 10 tons 2 cwts. of coal was produced. The earnings of the 5 workmen were about 5s. per shift, so that the coal was costing for their labour about 2s. 6d. per ton.

The conclusion arrived at, after all the experience gained, is that, in these coal-seams, the Stanley heading machine drives a place 11 feet wide about four times faster than hand labour, at about double the cost.

Mr. James Hamilton read the following paper "On the Report of the Royal Commission on Mining Royalties":—

ON THE REPORT OF THE ROYAL COMMISSION ON MINING ROYALTIES.

By JAMES HAMILTON.

The prolonged depression of trade which followed the abnormally active period of 1873-74 has been characterized by many improvements in mining. It has illustrated the uses of adversity and, from a scientific point of view, has amply repaid the anxiety it occasioned. One result directly traceable to it is the discussion of the laws affecting the ownership of land and minerals. So violent has this discussion been in some quarters that it might almost be described as an agitation against the system of mining royalties.

For years we have been told that mining royalties are a tax upon industry ; that they handicap the nation in competition for the trade of the world ; and that their abolition is absolutely necessary in order to revive our languishing industries. Some of the more advanced theorists have advocated the nationalization of land and minerals, and even of mines, as the only remedy for what they consider a crying evil.

The evidence of Sir Lowthian Bell given before the Commission on the Depression of Trade, in which he contrasted the amounts paid in royalties on a ton of manufactured iron in this country and in foreign countries, was largely responsible for the form assumed by the agitation. It was an apple of discord to that Commission itself, for no fewer than four several dissents from the majority report thereon were recorded.

In the course of this agitation, many extraordinary estimates of the amount paid in royalties in the United Kingdom were made. They ranged in amount from six million to seventy million pounds per annum, and from eight to thirty per cent. of the value of the gross output. Various attempts at legislation were made in the next few years, all more or less in favour of lessees. These attempts all failed, and served only to accentuate the absence of accurate knowledge on the subject already abundantly apparent.

Evidently the first necessity was information, and the Government in 1889 appointed a Royal Commission of a thoroughly representative character, and consequently composed of the most diverse elements, suggestive of the proverbial happy family. There were twenty-one

members, with Lord Northbrook as their chairman. All mining interests were represented—proprietors and proprietors' legal and mining advisers, colliery and metalliferous mine-owners and their agents; lawyers, economists, and the more staid and conservative section of the miners as well as the more advanced and revolutionary. The Commission was instructed—

To enquire into the amounts paid as royalties, dead-rents, and way-leaves on coal, ironstone, iron-ore, shale, and the metals of mines subject to the Metalliferous Mines Act, 1872, worked in the United Kingdom, and the terms and conditions under which those payments are made, and into the economic operation thereof upon the mining industries of the country, and further to enquire into the terms and conditions under which mining enterprise is conducted in India, the Colonies, and foreign countries by the system of concession or otherwise and the economical operation thereof.

The enquiry has just been completed, after upwards of three years' labour, and the results are now before the public in five bulky blue-books, containing more than twenty thousand questions and answers; and tables, diagrams, and appendices without number.

One of the first and most important effects must be to clear away the confusion of thought which was a striking feature of the discussion and agitation leading up to the appointment of the Commission, and to shatter what has been a very effective weapon in the hands of men skilled in the means of raising public clamour. Now that the report is in their hands royalty owners may breathe freely, if indeed they ever contemplated the result with aught but calm confidence in their own integrity. The beneficial effect of the enquiry is already evidenced by the rapidity with which the subject has ceased to interest, a result helped, no doubt, by the swing of the trade pendulum towards the prosperous side.

In carrying out the enquiry entrusted to them the Commissioners issued a series of questions to coal-owners' associations, and to a committee of royalty owners, with the object of eliciting information as to the conditions of mineral leases, fixed rents, and royalties charged, and the methods of assessing them; the provisions affecting surrender and assignment, way-leaves, and shorts; and generally any question or matter considered as a grievance, or which it was desired to bring before the Commissioners. The various associations were afterwards allowed to support their replies by verbal evidence. Miners' representatives were also heard; and information upon foreign and colonial systems was obtained both by circular and by examination of experts.

The total amount of royalties and way-leaves paid on minerals in the United Kingdom during 1889 are shown in the following table; it being

noted that so far as the figures apply to England and Ireland they are merely estimates, based upon the output for the year, and such information as to average royalty in various districts as was elicited in evidence, together with the personal knowledge of the Commissioners.

		Output, 1889. Tons.		Royalties. £		Way-leaves. £
Coal—						
England and Wales	...	153,596,360	...	3,374,235	...	188,100
Scotland	...	23,217,163	...	629,902	...	13,816
Ireland	...	103,201	...	4,216	...	—
Totals ...	...	176,916,724	...	4,008,353	...	201,916
Ironstone and iron-ore—						
England and Wales	...	13,319,685	...	525,239	...	14,781
Scotland	...	1,061,734	...	33,824	...	
Ireland	...	164,686	...	2,059	...	
Totals ...	...	14,546,105	...	561,122	...	14,781
Totals—						
Coal	...	176,916,724	...	4,008,353	...	201,916
Ironstone and iron-ore	...	14,546,105	...	561,122	...	14,781
Other metals ...	...	—	...	87,068	...	—
Totals ...	...	—	..	4,656,543	...	216,697

The royalties per ton upon coal in the various mining districts are estimated as follows :—

Coal-fields.	Maximum.	Minimum.	Average.
	s. d.	s. d.	s. d.
Northumberland	0 10	0 2½	0 4
Durham	0 10	0 2½	0 5
Cumberland and Westmoreland	0 8	0 3	0 6
Lancashire and Cheshire	—	—	0 6
Yorkshire	—	—	0 6
North Staffordshire and Cannock Chase	—	—	0 5½
South Staffordshire, Warwickshire, and Worcestershire	0 8	0 3	0 6
Derbyshire, Nottinghamshire, and Leicestershire	0 6	0 4	0 4¾
Shropshire	—	—	0 6
Somersetshire	0 9	0 5	0 6
Gloucestershire—Bristol	—	—	0 6
„ Forest of Dean ...	—	—	0 3
Monmouthshire and South Wales ...	0 9	0 4	0 6
North Wales	0 10	—	0 4
West Scotland	1 3	0 4	0 7
Fife and the Lothians	1 2	0 3	0 6

Whatever the procedure by which minerals in the United Kingdom became private property, there is no disputing the fact that, with the exception of gold and silver, they are now as a general rule vested in the surface owner, and nationalization is therefore only possible by compensa-

tion or by confiscation. If an attempt were made by compensation it would not, in the opinion of competent witnesses, be a profitable undertaking for the State at the price that would be assessed by valuators; while even the most extreme witnesses hesitated to advocate confiscation when placed in the witness box—a situation which exercises a salutary and subduing effect on most men. As to this policy of nationalization it is curious to note that new countries generally are not directing their policy to avoid private ownership either of land or minerals, but are following a policy which will bring them exactly into the position in which we in this country now find ourselves. They are doing this with their eyes open. While European nations had not the experience of older countries in this matter before them as a warning or example, it is far otherwise with the Colonies and America; and, judging from their policy, they see nothing to alarm them in the results of our system. The government of the United States, for example, retains neither land nor minerals as national property, but freely disposes of both to individuals or corporations. An American witness said "The object of the Government then is to develop the mineral resources, . . . and to get a clear title into the hands of a citizen as rapidly and as cheaply as possible, and then to take its own hands off."* The troubles that have arisen out of separation of ownership of surface and minerals prove in our own experience the wisdom of that course, and a new country with its need of men and capital finds its strongest attraction in the land hunger firmly rooted in the breast of every man.

Separation of the ownership of the surface and mineral, when the latter belongs to the State, was found long ago in Scottish history to make it the interest of the surface-owner to conceal or prevent the discovery of minerals on his land. No good, certainly much trouble, and possibly some loss, must inevitably come to him by the working of minerals on his land; and this has no doubt been a factor in producing individual ownership. In some of the Australian Colonies a somewhat similar difficulty is being experienced.

All things considered, it is by no means certain that private property in minerals is a disadvantage. Given State ownership of mines with or without land also (the nationalization of land and of minerals is really but one question), and we have many unsolved difficulties to face which were far from successfully met by those who advocated the change before the Commissioners.

There is, for example, the question of how to prevent royalties or their equivalent from springing up. Unless worked as a State department it is

* Third Report, page 15, question 14,385.

difficult to see on what system the mines are to be worked, and that alternative is a risky one. If leased to private parties, no satisfactory means of selecting the lessee has been suggested other than by competition. A fixed royalty has been proposed, but no witness could say how a tenant should be chosen when two or more offer the same fixed royalty for a mineral field. To proceed by concession based on the right of discovery is impossible in this country where the mineral resources are so well known. Under any system of concession, even if a concessionaire be forbidden to sell or sub-let, the royalty inevitably comes in. Death ultimately claims concessionaire or tenant, and his property must be realized—presumably by sale in the open market. The price paid by the purchaser, over and above the value of the machinery on the ground necessary for working the mines, takes the place of a royalty, inasmuch as it is his estimate of future profits from the concern and includes the capitalized equivalent of a royalty: Then, as one witness put it, if there were no royalty there would be no landlord to squeeze in times of depression. The witnesses were unanimous in preferring to deal with an individual landlord, rather than with a Government department, hampered by being in trust for the State, and with the certainty of criticism and the uncertainty of what use their political opponents might make of their actions whatever they might be.

In this connexion take the opinion of an American witness* :—

The payment of royalties . . . has assisted the development of the minerals of the United States. My reason for saying that is, that I have had a chance of observing in the Western United States, for a period of nearly twenty years, the operation of a system without royalty, namely the system of free license to mine on the public lands, and I have found there that an element of stability and progress and of real regulated industry was introduced, when these public lands were made private property, which is only to say in other words when they were made subject to royalties. It seems to me that in our country, so far as we have got with the question, waiving all difficulties, which you may have encountered in your more advanced position of development; in our country, it is perfectly well illustrated that private property and the enlightened self-interest of private owners is a far better atmosphere for the development of a regulated and a prosperous industry, than any amount of free gift on the part of the State. We went and made every mine on the Pacific Coast from the Rocky Mountains to the Pacific Ocean free of royalty, and we just had chaos, anarchy, and no progress, no stable order, no clear and definite title. Then we went laboriously to work, and have at last got it round, so that the principal mines are in private hands, and they charge whatever royalty they can, and we have got more industry, and more safety and security and profit by introducing the principle of private responsibility and private interest. Until anybody can show me a case where the opposite has taken place, I must confess that I feel as if that was, for my country in its present condition, a conclusive answer

* Third Report, page 19, question 14,452.

to the whole subject. I have been accustomed to say at home over and over again that it would be better for the United States to-morrow, to give up all its mineral land and deliberately convey it to individuals for nothing, in order to have somebody own it instead of the Government.

It was shown in evidence that in Spain where the minerals are granted by concession to individuals, the concessionaire generally occupied the position of a landlord here, disposing of his concession to the actual worker of the minerals, reserving a royalty, or obtaining a capitalized equivalent of a royalty, by a sale of his concession.

In other European countries the position is practically the same, although, theoretically, in some cases, there are restrictions upon the liberty of the concessionaire in the matter of sub-letting, and in the power to resume a concession in certain circumstances. These conditions are rarely or never enforced, and property in minerals is practically as absolute as that of a freeholder here. The concessionaire seldom leases his minerals; but he as seldom works them himself, finding it more to his advantage to sell his right.

By whatever system the State deals with mineral property it appears that the royalty system or an equivalent inevitably comes into operation, and any attack on royalties as such is as futile as beating the air.

State ownership of minerals, though clearly not the unmixed good its advocates claim, has certain advantages. It affords greater facility for working minerals economically, for dealing with way-leaves, and for arranging and working mine-drainage schemes, which grow in importance with the age of our coal-fields, and will be a difficulty to be overcome by future generations of mining engineers. These advantages, however, can only be secured by avoiding the system of concession, and by keeping the letting of minerals in the hands of a State department, to be worked with the object of getting for the State the fair value of its property for the benefit of the nation. But nationalization is not meantime within the range of practical politics, and it is unnecessary to discuss it further.

It has been pointed out by various authorities that a mineral lease is not a lease at all, in the ordinary sense of the word; as applied to agriculture, for example, where the value of the leasehold is not diminished, but, by careful husbandry, is maintained, if not enhanced. Under a mineral lease there is no increase, but the removal of part of the property and a consequent diminution of value. The instrument under which the lessee works is thus really a sale of part of the property. Hence the necessity for a payment proportionate to the quantity of mineral removed, and also for a fixed minimum rent; the former to secure to the landlord a revenue

from his property equivalent to decrease in value, and the latter to prevent the locking up of the minerals without any return at all. The need for this double security was very early recognized in the North of England and in Scotland; for in almost the earliest leases extant, alongside the stipulation of a fixed rent the maximum number of hewers is agreed upon, a somewhat crude method of meeting the case, but doubtless sufficient for the needs of the time.

This has not apparently been so early recognized farther south, or if recognized has not been acted on, as cases are comparatively common in Wales where very long leases of large areas of mineral property are, or were lately, in force under fixed annual rent only, and miserably inadequate rent at that. It is stated that the Dowlais Iron Co. paid only £100 per annum for a century prior to 1847; and in 1848, when a lordship was stipulated under a new lease, upwards of £20,000 was paid for the year's output.

The landlord being thus protected by a fixed rent, the lessee seeks to secure himself against loss of shorts or overpaid fixed rents by stipulating for the right to work, free of lordship, coal equivalent thereto, generally limited to a certain period, to make up shorts. The English coal-owners appear to consider this limitation of the time to recoup overpaid fixed rents as very much of a grievance; but without it a fixed rent is no adequate protection for a lessor against the locking up of his minerals, while on the other hand the lessee seeks greater security for capital outlay by taking the largest field he can get at the lowest possible rent. If greater security for capital invested is desired by a leaseholder he must pay for it by increased fixed rent, in order to induce the proprietor to give him a larger field. The amount of the rent is, or ought to be, determined so far as a lessee is concerned, not by the area of mineral field, but by the amount of mineral he can—one year with another—raise and dispose of. To the lessor the determining factor is the area, and the conflicting interests will be compromised in favour of the party in the stronger position under economic laws. So long as the parties are in a position of equality, a fair and reasonable bargain, so far as their information goes, will be struck. But if we should call no man happy till he is dead, so we call no mineral lessee fortunate till his lease is discharged. Difficulties may arise in winning and working which were not anticipated and which it was impossible to forecast, and the working of the minerals thereby so delayed that the lessee is unable to work up his shorts; in other words he pays for mineral which he is unable to work. It is true that if the lessee insists on having a large field and greater security for his

capital it is fair he should give an equivalent; but in this matter at least the risks, because unknown and incalculable, are mainly with the lessee.

In the circumstances, probably few will object to the conclusion of the Commission in favour of some such remedy as was provided by the Bill introduced into the House of Commons in 1888, "Giving the Court of Chancery power to give the lessee, if the non-extraction of the mineral was not owing to his default, a period of grace in which to work the coal for which he has paid without further payment of rent, unless the landlord elect to repay the overpaid rent instead."*

The principle of compensation for unexhausted improvements at the end of a lease was urged by some associations and individuals; but it is dismissed with a summary of evidence given before the Commission. In Scotland, practically the only permanent improvements for which a tenant does not receive compensation are the shafts, permanent roads in workings, formation of railways, sidings and other earth-works, which are of no value to him, and of little to the proprietor unless the colliery is to be continued without any interval. But as anything which reduces the unknown risks to a lessee must be alike to his and to the lessor's advantage, it appears a legitimate direction for reform.

Evidence was brought before the Commission tending to prove hardship in the restriction of the right of a tenant to assign his lease. Such right of assignation is, from a lessee's point of view, a very desirable stipulation, and, with sufficient safeguards, not unfair to a lessor. While a clause precluding assignation is almost universal in mining leases, it appears that "a covenant in restraint of alienation in the case of a mining lease is not regarded by the court as a usual covenant;" and that, consequently, an agreement to enter into a formal lease with all the usual covenants, does not entitle the lessor to insist on a clause excluding assignees. Inasmuch as the Conveyancing and Law of Property Act appears to proceed upon the principle that covenants against assignation should only be used for the reasonable protection of a lessor, and not as a means of exacting money by way of fine, the Commission consider that it would not be an undue restriction upon freedom of contract if it were provided that all covenants against alienation be held to mean, that it is not to be done without the proprietor's consent, and that such consent shall not be unreasonably withheld. This appears to meet the case of the lessee (as brought forward in evidence) in a way that gives fair protection to the lessor, its weakness being the indefiniteness of the expression "unreasonably with-

* Final Report, page 16.

held;" but that is an objection which may be urged against all legislation, and the interpretation may be safely left to arbitration, or to the courts.

The Commission do not favour the creation of a special tribunal to deal with mining questions such as shorts, compensation for improvements, etc., considering the advantages of such a court not sufficiently established by the evidence.

An important part of the case laid before the Commission by coal associations, particularly by those of the North of England, referred to way-leaves. This being the oldest mining locality in the kingdom, and collieries having been established before public railways were in existence or sufficiently developed to meet the needs of the district, many of the collieries have private lines connecting the pits with the shipping-places on the Tyne. These lines are way-leave lines, and payment has to be made to the proprietors of land passed over for right of way. Hence the greater importance of this question there. This is shown by the estimated proportion of output subject to way-leave:—Northumberland $\frac{1}{3}$, Durham $\frac{1}{2}$, Yorkshire $\frac{1}{4}$, Monmouth and South Wales $\frac{1}{3}$ (in other parts of England payment for way-leave is only made in exceptional cases). For the whole kingdom the proportion is less than a $\frac{1}{4}$. It was contended for those opposed to way-leaves, and the evidence was principally from mine-owners, that payment for way-leave ought to be determined by the damage to the grantor of the right, and not by the value of the right of way to the grantee. They did not ask to be let off for the mere agricultural value of the land taken, but were quite willing to pay full value for any damage of whatever kind, for amenity or for intersection. It was held, unassailably from their point of view, that the damage to the grantor of the way-leave was not proportionate to the amount carried over the ground, but is the same for 1 ton as for 1,000, and that, therefore, the demand for a tonnage rate over and above the payment for damage done is not at all a fair one. Many instances were given in evidence, in a very effective way, of the annual payment per acre for ground occupied for way-leave purposes, being many times the full market value of the land. One instance cited by a witness may be mentioned as a kind of *reductio ad absurdum* of way-leaves. A mine-owner worked coal from an enclosed common where, as is usual in such cases, there was severance of ownership of minerals and surface, the former belonging to the lord of the manor. For purposes of drainage a shaft existed on the property of a certain small surface-owner, who could not and did not exercise any restrictive right to the operations of the coal-master, so long as he drained only the coal of the lord of the manor by

of actual damage to himself. When a number of small proprietors, whose lands severally are each too small to repay a winning, combine and let to one lessee, the owner who has the shafts on his property has a certain disadvantage in damage and permanent disfigurement of his estate, and to some extent, it may be, delay in working out his mineral, but against that may fairly be placed the advantage of having control of the shafts till his mineral is worked. With a property sufficient in extent to repay a winning for itself, then, till the mineral is exhausted, the granting his tenant the right to work from other lands defers the income from his own, a substantial loss for which he is justly entitled to compensation by way-leave. Here a tonnage rate is in exact correspondence with the conditions. With underground way-leaves too, when the quantity of mineral to be worked under way-leave would justify a separate winning, a proportion should fall upon the tenant, for he saves the cost of another sinking and the erection of another fitting.

It was urged in evidence that the shaft and underground ways by which the foreign mineral is worked, are made by the lessee at his own expense, and that the landlord has no right to a way-leave, at least in the case where his own mineral is exhausted; but there remains the fact that the lessee is supposed to have repaid himself for his capital outlay by working the proprietor's own coal, and cannot fairly claim the right to recoup himself a second time. In many cases, too, the continuance of a working pit on the lands is disadvantageous both for the amenity of the estate and on æsthetic considerations, largely sentimental considerations no doubt, but nevertheless possessing a value in hard cash.

It appears that on the Continent generally there exists a right to take land compulsorily for carrying minerals, after enquiry by a Government department, on payment for ground occupied of full compensation, which in some cases means double the ordinary value of the land. This power does not exist in the United States, but there, compulsory powers to acquire land for a railway are much more easily and cheaply obtained. It is not necessary to prove public necessity: that is the promoter's concern. In the words of Mr. Carnegie:—"Any five men can organize a railway company, obtain a charter from the State for eight shillings, and go ahead. This charter gives them the right to condemn property, paying full value therefor, as assessed by the viewers (valuators)."*

The conclusion of the Commission is:—

We think that all applications for relief in such cases ought to be made to a judicial tribunal, which might be trusted to have a due regard to the existing rights

* Third Report, page 12, question 14,333.

of the owners of property over or through which passage for minerals is required, the usual charges for way-leave prevailing at the time in the district if not unreasonable, and the relative and respective rights of proprietors and lessees of the mineral property requiring way-leave. . . . We may add that we think that if such a remedy as we have suggested were open to persons who conceived themselves to be aggrieved by the unreasonable refusal of facilities for the passage of minerals, difficulties would be readily arranged by private agreement, and that only in very rare instances, if ever, would it be necessary to have recourse to compulsory proceedings.*

Severance of surface and mineral ownership has caused no little friction during the last few years. The decisions of the Law Courts have established the principle that the surface-owner is presumed to have the right of support until it is shown that his titles do not give him it. In giving judgment in the case White *v.* Dixon, Lord Blackburn said, "There is no controversy now, as to what is the law, both of England and Scotland, as to the ordinary right of support." . . . Further he says, "It is in every case a question of construction of deeds . . . to ascertain whether the proprietors of the surface have accepted them under a contract to give up the support, but I think the burthen is on those who say there is such a contract to show that there is an intention to that effect appearing on the face of the titles." This implies that the surface-owner can prevent the mineral owner so working his mines as to lower the surface even on paying compensation for damage done, and this in many cases gives him the power to render the property of the mineral proprietor valueless. Lord Blackburn thought that seeing stoop-and-room was the invariable method of working of that day, the stoops were left with the intention of supporting the surface permanently; but there is doubt approaching certainty that such was not the case in ordinary workings. The principal intention of stoop-and-room was undoubtedly to preserve the roads in the workings, and the stoops were not sufficient to maintain the level of the surface permanently—a fact that could scarcely have escaped observation. The extraction of the stoops was a later improvement in mining.

While this case did not seem to establish the rule it called attention to the law on the point, and surface-owners have naturally taken advantage of their position to get a share of the value of the coal. It has, in many cases, pressed heavily upon lessees also who were under onerous obligations to the lessor, and had sunk their capital in mines which they afterwards found they were at liberty to work only by methods that were impracticable in the circumstances. The case has been met in many instances by a payment to the surface-owner for the right to lower the surface.

* Final Report, page 21.

[illegible]

[illegible]

[illegible]

[illegible] and perhaps the most important question remitted [illegible] is that of the [illegible] operation of the royalty system; [illegible] part of the report is devoted to its elucidation. In treating of land [illegible] that rent does not enter into the cost of the produce of a farm, because the prices obtained must be such as will repay the cost of production on the poorest land under cultivation free of rent; and conversely, the price obtained will draw the line between cultivable and non-cultivable land. Consequently rent is what is paid for the superior advantages of rent-paying land due to nearness to markets, natural productiveness of the soil, and ease in cultivation. Similarly, rent or royalty of minerals is the equivalent of superior advantages of a mineral field in geographical position, quality of produce, cost of working, and an infinite number of factors affecting the price at which the mineral can be profitably placed in the market. It is not quite so simple as the case of land. As has been already shown, royalty is not an exact equivalent of agricultural rent, inasmuch as the working of mineral from an estate deteriorates its

* Final Report, page 22.

value. A proprietor, therefore, is never prepared to lease his mineral except for a valuable consideration; nor, which is the same thing, to work them himself without at least the expectation of a profit to include a royalty over and above what a lessee would consider a satisfactory return. The working of minerals also is impossible without damage to the surface by hideous rubbish-heaps, by clouds of smoke hurting vegetation, and by subsidence, with the unsightliness of swampy ground and soured crops. The owner must therefore be paid rent or royalty to induce him to let; and consequently rent or royalty of minerals must enter to some extent into the price thereof to the consumer. Now, the function of a royalty is to equalize, or tend to equalize, the worst and best mines in competition in the open market. A perfect royalty system would exactly counterbalance the advantages of the better mines, and put all on an equality in competition; inasmuch as it would be an exact money equivalent of these advantages. Needless to say, this is unattainable; for, apart from the physical uncertainties of a mineral field and the complicated nature of the problem, the means of accurate judgment are not generally available till long after the royalty has been fixed. But its action, if necessarily imperfect, is in the main beneficial in preventing a monopoly with all its evils in the hands of the owners of the best mines, for many of the poorer mines could not be worked at all in the absence of all royalties.

The extent that royalty enters into price will, by parity of argument with the case of rent of land, be the royalty paid by the poorest mines, being the lowest amount that will induce a proprietor to let his minerals. The price at which a mine-owner will sell the produce of his mine is not determined merely by what will pay, but what the law of supply and demand enables him to obtain from the consumer; and the effect of abolishing royalties, so far as the consumer is concerned, would appear theoretically to be a lowering of price to the extent of the smallest royalty, inasmuch as that would maintain the relative position in competition of the mines at work. Given that the demand is just equal to the production of the mines, each at its maximum output, there would be no inducement to lower prices even to that extent, but the moment one mine-owner found it necessary or desired to draw a larger share of the trade the price would begin to fall. The effect might not, and probably would not, be immediate in brisk times or in face of a rising market; but it must ultimately tend to reduce prices somewhat more than the amount of the lowest royalty; and in this way abolition of royalties would almost certainly lead to the opening of poorer mines, or the re-opening of those abandoned as unworkable under royalty, and more mineral would be produced than

could be profitably disposed of. Then would follow what we call depression of trade, with the certain effect of inducing the owner of the better mines who had obtained relief by abolition of royalties to a much greater extent than the poorer, to lower prices to command trade below the point at which the latter could compete and compel their abandonment. As the collieries in existence could easily produce more than they do, the inducement to do so being increased by greater profits—as he that gets much seeks to get more—the ultimate effect would probably be to crush out some of the mines now paying the minimum royalty, and so raise the dividing-line between workable and unworkable, and making the fall of price at first somewhat more than equal to the present lowest royalty. This might be only temporary, or be modified in the event of combination of the richer mines to command the market and create a monopoly, but the great volume of the trade, the extent of the coal-fields and facility of transit, not to speak of the re-opening of poorer mines in face of enhanced prices, would act as a restraining force in any movement of the kind.

All this assumes that no benefit would reach the workmen through abolition. Professor Sorley, who has studied the subject carefully, and who spoke with more authority than any other witness on this aspect of the question, says :—

My view is this: that what I have called the minimum royalty might be expected to go to reduce price, and that the remainder of the royalties charged on all mines paying above the minimum would go into the pockets of the lessees or employers.*

There is nothing left for the workmen, and the probabilities are rather in favour of the effect of abolition being to their disadvantage. For if poorer mines are driven out of the market the workmen must find employment in the better mines in producing the larger output required therefrom. But the productive capacity per workman in the richer mines would be greater simply because they are richer. Consequently fewer workmen would be required for an output to meet the demand, and the labour market being overstocked wages would fall; for it has yet to be shown that any organization whatever can permanently maintain the rate of wages in such circumstances. The matter is summed up by the Commission thus :—

The whole coal industry would be dislocated by the stoppage of the mines least favourably situated, and the consequent loss of employment on the part of the workers in such mines. But some compensation would result from the employment of additional workers in the mines that obtained the trade. In so far as the lessees of the poorer mines were driven out of the trade, it would be through the lessees of the better mines offering coal at a price that would prevent competition; to the extent of this fall the consumer would derive an advantage, but this advantage would

* Third Report, page 164, question 18,351.

be only temporary, as it would probably be withdrawn as soon as the lessees of the better mines obtained control of the market. If the miners could obtain a share in the benefit of the reduction the advantage to them would be unequal, varying from district to district and from colliery to colliery; and in so far as obtained it would diminish the benefit to the consumer.*

The report also discusses the effect of a partial reduction of lordship on wages, with the result that the evidence is against the workmen being benefited, except by a continuation of employment or avoidance of reduction at the colliery affected; and in the case of a general reduction, limited of course by the amount of the lowest royalty, it is thought that possibly the miners might, by prompt action, intercept the whole or part of the reduction. It is difficult to see how this could be aught but temporary if it did happen in any degree.

The following table shows the average wages per annum paid to all classes of colliery workmen in the United Kingdom, France, Belgium, and Germany. The figures for this country are merely an estimate, but for the others they are accurately got from the statistics of the Government departments of mining.

	1888.			1889.			1890.		
	£	s.	d.	£	s.	d.	£	s.	d.
United Kingdom ...	49	16	0	60	6	0	71	16	0
France	45	5	10	47	18	4	53	17	7
Belgium	36	4	2	38	16	8		—	
Liége...	39	10	0	41	8	4	48	1	8
Germany, Westphalia	43	3	0	47	1	0	53	7	0
Saarbrücken ...	42	2	0	46	13	0	55	14	0

It is to be noted that the average wages are higher in the United Kingdom per workman, and that wages here appear to be more sensitive to the fluctuations of the market than on the Continent. The information conveyed by the table is not conclusive as to the condition of the miner, for the purchasing power of money may be different, but a considerable deduction may be made and still leave the British miner better off financially than his Continental brother. He has also an advantage in shorter hours of labour.

The relative proportions of the selling price of coal taken by the royalty owner and by the labourer is interesting and important in view of much that has been said in the course of the agitation. The ratio of the average royalty to the average selling price in the several coal-fields is given as follows† :—

* Final Report, page 43. † The average royalty has been ascertained from the evidence, and the average selling price from the mineral statistics, which are admittedly only approximately correct.

Coal-field.	Average Selling Price per Ton. 1888.	1889.	Average Royalty per Ton.	Percentage of Royalty to Selling Price. 1888.	1889.
	s. d.	s. d.	d.		
Northumberland	4 4	5 4·7	4	7·7	6·18
Durham	4 5·3	5 1·8	5	9·38	8·09
Cumberland	4 10·8	5 9·2	6	10·2	8·67
Westmoreland	7 0	7 0	6	7·1	7·1
Lancashire—North and East ...	5 6	6 8	6	9·09	7·5
„ West	5 4	6 3	6	9·37	8·0
Cheshire	6 0	7 0	6	8·3	7·14
Yorkshire—East and West ...	5 1·5	6 3	6	9·75	8·0
Staffordshire—North	6 0	6 6	5½	7·6	7·06
„ South	5 4	6 5	6	9·37	7·8
Warwickshire	5 0	7 0	6	10·0	7·14
Worcester	5 0	6 5	6	10·0	7·8
Derbyshire...	5 6	7 9	5	7·57	5·37
Nottinghamshire	5 0	7 0	5	8·33	5·95
Leicestershire	5 1	7 1	5	8·19	5·88
Shropshire...	6 0	7 0	6	8·33	7·14
Somersetshire	7 7	8 1	6	6·6	6·18
Gloucestershire—Bristol... ...	7 7	8 10	6	6·59	5·66
„ Forest of Dean	7 7	8 10	3	3·29	2·83
Monmouthshire	5 11	7 5	6	8·45	6·75
South Wales—Glamorgan, East	5 9	6 9	6	8·69	7·40
„ „ West	5 10	8 3	6	8·57	6·06
Scotland—Lanarkshire, East ...	3 8	5 0	6½	14·77	10·83
„ „ West ...	3 10	5 0	6½	14·13	10·83
„ Ayrshire	4 0	5 2	6½	13·54	10·48
„ Fife	4 0	5 6	6	12·5	9·09

Unfortunately, there is no similar information showing the ratio of wages to selling price; but the following individual cases have, at least, the merit of being based on more exact information. Mr. Hewlett of the Wigan Coal and Iron Co., Limited, gave the following evidence:—

	Arley Mine. Half-year ending. Dec. 31, 1880.	Arley Mine. Half-year ending. Dec. 31, 1889.	Yard Mine. Half-year ending. Dec. 31, 1880.	Yard Mine. Half-year ending. Dec. 31, 1889.
Average selling price per ton ...	4s. 11·8d.	6s. 5·1d.	4s. 10·2d.	6s. 7·5d.
Percentage proportion of selling price—				
Underground wages	50·8	—	58·5	—
Surface wages	7·4	—	7·5	—
Total wages	58·2	54·2	66·3	56·4
Other payments	40·8	27·1	36·3	23·4
Royalty	10·9	8·4	10·8	7·9
Total cost	109·9	89·7	113·4	87·7
Balance	Loss 9·9	Gain 10·3	Loss 13·4	Gain 12·3

A comparison of these figures shows that the percentage of the selling price of coal taken by labour decreases as coal rises in price.

There appears to be a general feeling in favour of a sliding scale lordship on the basis of the selling price. The sliding scale has been introduced rather extensively in the North of England in recent years, and few of the witnesses had any objection to it although some preferred, as they put it, to know exactly what they had to pay. What has prevented its adoption much more frequently than has been done in Scotland, has been the want of a public standard to regulate the royalty. It is a very simple matter in the case of ironstone, where we have the price of pig-iron warrants published daily, but there is nothing to take the place of this in the case of coal. Some coal royalties, when iron-masters are lessees, are regulated by the price of pig-iron warrants; but there is no necessary connexion between that price and the price of coal in the market. The only available means of arriving at the average price is by an examination of the books of the lessee, who naturally has no particular liking for the operation. The result is friction, and the tenant is hampered in the conduct of his business; for many things have to be done to satisfy customers that a proprietor cannot allow to affect his royalty. What is the actual average sale price at the colliery is not by any means easy of ascertainment, and the system opens the way to fraud should anyone be so disposed. The tendency of a sliding scale is to enable the coal-master to work more regularly. It also reduces in some measure his risks, by eliminating one unknown quantity from his calculations in making his bargain, namely, the uncertainty of the fluctuations of the market. It is to be expected, therefore, that a sliding scale would be for the benefit of the lessee, for the reasons stated, and also for the lessor, as his tenant having eliminated one uncertainty could do with a smaller margin for contingencies, and thus the fixed royalty should be less than the average of the sliding scale as suggested by one member of Commission.

It was given in evidence—

That the substitution of a sliding scale for the fixed royalty has in times of depression enabled a colliery to be kept going that would otherwise have been closed; and the miners have thus benefited by the lessees being enabled to afford them continuous employment.*

On this subject Sir Lowthian Bell said:—

I should like to see a sliding scale introduced, if for no other reason than to satisfy the men. They, when bad iron trade comes, know that we, their employers, first suffer, then their wages are reduced, and even railway companies make some

* Final Report, page 41.

concession in their rates. Men therefore look upon it as a great hardship that the landowners, who are receiving, no doubt, collectively, a large sum from the minerals, do not suffer at all. But the men overlook the fact, I think, that the landlords in good times have never received any advantages.*

This aspect which the fixed royalty assumes to the miner in times of depression is largely responsible for the agitation which arose and led to the enquiry; and if a sliding scale would remove this imaginary injustice, its extensive adoption is well worth a trial. At the same time the benefit to be derived would not counterbalance the disadvantage attending legislation for such a purpose. The witnesses most strongly in favour of a sliding scale would have none of it by such means It would be the equivalent of payment in kind—the earliest form of rent—as it is now the device used in leases as a safeguard in the event of the unexpected discovery of mineral of uncertain value.

The effect of royalties upon foreign competition has been much discussed in recent years, and an impression widely prevails that this country is heavily handicapped by the royalties paid. If, as already argued, only the minimum royalty enters into the price, then the comparison so far as affecting foreign competition is between the minimum royalty here and with our competitors.

The minimum royalties on coal are:—

	Per Ton.		Per Ton.
United Kingdom	2½d.	South Wales and Yorkshire	4d.
Scotland, West	3d.	Westphalia	1⅜d.
„ East	4d.	Belgium ... ... under	1½d.
Northumberland and Durham	4d.	France	nil.

In these relative figures we have, then, our apparent disadvantage as compared with our neighbours across the Channel. How insignificant its effect is shown by the following tables, which give, between 1880 and 1891, the percentage of increase in output and exportation in the United Kingdom, Germany, France, and Belguim; and the increase of exportation of coal to these countries:—

TABLE SHOWING OUTPUT OF COAL IN 1880 AND 1891.

	1880.	1891.	Increase.	Average Increase per Annum.
	Tons.	Tons.	Tons.	Per Cent.
United Kingdom ...	146,818,622	185,479,126	38,660,504	2·14
France	19,361,564	26,024,893	6,663,329	2·72
Belgium	16,886,698	19,675,644	2,788,946	1·40
Germany	46,973,600	73,715,653	26,742,053	4·18

* First Report, page 46, question 1,049.

TABLE SHOWING EXPORTS OF COAL.

	1880.	1891.	Increase.	Average Increase per Annum.
	Tons.	Tons.	Tons.	Per Cent.
United Kingdom ...	23,628,000	38,226,000	14,598,000	4·92
France	603,000	941,000	338,000	4·54*
Belgium	4,525,000	4,851,000	326,000	0·71
Germany	7,236,450	9,145,187	1,908,737	2·37

TABLE SHOWING EXPORTS OF COAL FROM UNITED KINGDOM.

	1880.	1891.	Increase.	Average Increase per Annum.
	Tons.	Tons.	Tons.	Per Cent.
France	3,715,762	5,258,346	1,542,584	3·21
Belgium	280,015	607,779	327,764	8·06
Germany	2,241,064	4,171,993	1,930,929	6·41
Russia	1,504,000	1,502,000	—	—
Sweden and Norway ...	1,317,000	2,439,000	1,122,000	—
Italy	1,535,000	3,551,000	2,016,000	—
Denmark	864,000	1,437,000	573,000	—
Holland	498,000	776,000	278,000	—
Portugal, Azores, and Madeira	339,000	624,000	285,000	—
Spain and Canaries ...	900,000	1,982,000	1,082,000	—
Turkey	289,000	393,000	104,000	—
Egypt	652,000	1,578,000	926,000	—
Brazil	359,000	798,000	439,000	—
Gibraltar and Malta ...	697,000	826,000	129,000	—
British East Indies ...	1,020,000	1,233,000	213,000	—
Other countries ...	2,509,000	3,905,000	1,396,000	—
Coal shipped for steamers in foreign trade..	4,926,000	8,536,000	3,610,000	—

From these tables it will be seen that since 1880, our exports of coal have increased largely to every European country except Russia. The total exports have increased in a greater ratio than the total production, and the exports to France, Belgium, and Germany (our chief competitors) have also increased at a more rapid rate than the respective outputs of these countries, as well as more rapidly than our own output. These statistics prove more conclusively than any abstract argument can do that under private ownership of minerals and royalties we can more than hold our own in foreign competition.

In this connexion a most instructive table showing variations in freight per ton during three years ending June, 1890, from the Tyne and

* This shows too favourably for France as its exports are small comparatively and fluctuate very much. In 1888 the exports were only 629,000 tons.

South Wales to various ports is given, from which the following is extracted:—

Destination.		From Tyne.		From South Wales.
		s. d. s. d.		s. d. s. d.
Rouen ...	...	5 9 to 7 0	...	4 7½ to 8 6
Havre ...	...	4 6 „ 5 6	...	4 3 „ 7 0
Hamburg	...	4 6 „ 5 6	...	4 6 „ 8 0
Barcelona	...	10 0 „ 11 6	...	11 0 „ 15 0
Odessa ...	...	7 6 „ 9 6	...	7 0 „ 11 0
Cronstadt	...	4 3 „ 6 0	...	5 0 „ 12 6
Bombay	...	14 0 „ 23 0	...	14 0 „ 27 0
Alexandria	...	8 0 „ 11 0	...	7 9 „ 12 3
Valparaiso	...	15 0 „ 35 0	...	— „ —

In the face of such variations, the lordship takes an insignificant place, as affecting our ability to compete on the Continent for the coal trade of these countries themselves. In competition with these countries for outside markets these do not apply.

The economic effect of royalties upon the iron trade would appear to be of even less importance, if that be possible, than in the case of coal. The production of iron ore in Spain is an object lesson for those who advocate State ownership and abolition of royalties, and shows how difficult it would be to get rid of royalties. The ore belongs to concessionaires, who pay nothing to the State, and yet the royalties paid by those who work the ore are practically the same as are paid in Cumberland under private ownership. In the face of the very high tariff imposed upon the importation of manufactured iron into so many countries it is evident that the sum paid in royalties in the United Kingdom is comparatively unimportant. And that is not all, as the policy of many foreign countries is to prevent the importation of manufactured goods entirely, and a decreased cost here which allowed of profitable exportation of manufactured iron under existing tariffs would simply be met by an enchanced import duty. In Germany steel rails are subject to a duty of 20s. a ton, and in America pig iron pays a duty of 28s. a ton, and steel ingots 37s. 6d. a ton.

Those who gave evidence before the Commission were practically unanimous in the opinion that royalties had not retarded the development of the minerals of the country, and the statistics of output already given render the opposite view quite untenable.

The mining industry has suffered from too rapid development and over-production since 1874-75, and no part of the country suffered more severely from this than the West of Scotland.

Looking to the estimated coal resources of the country, one cannot help fearing that the development has been all too rapid, and wondering what will happen to the nation when its fuel is exhausted. Unless some new and much less wasteful means of utilizing the energy stored up in coal be discovered, and that speedily, the next generation even may begin to feel that coal is becoming scarcer and dearer.

The following is a summary of the conclusions of the Commission :—

I.—We estimate that the amount paid as royalties on coal, ironstone, iron-ore, and other metals worked in the United Kingdom in the year 1889, was £4,665,043; and that the charge for way-leaves for the same year was about £216,000.

II.—We are of opinion that the system of royalties has not interfered with the general development of the mineral resources of the United Kingdom, or with the export trade in coal with foreign countries.

III.—We do not consider that the "terms and conditions under which these payments are made" are, generally speaking, such as to require interference by legislation, but we recommend that some remedy should be provided for cases in which a lessee may be prevented, by causes beyond his own control, from working the minerals he has taken, and also for cases of certain restrictions upon the assignment and surrender of mineral leases.

IV.—We are of opinion that, where the surface belongs to one person and the subjacent minerals to another, greater facilities should be provided for the working of the minerals.

V.—We are of opinion that greater facilities should be afforded to tenants for life of settled estates in dealing with mineral property.

VI.—We think that facilities for granting mineral leases for longer terms should be given to corporations and public bodies which do not already possess sufficient powers in that respect.

VII.—We recommend for the favourable consideration of Parliament any measure which may be introduced, with the concurrence of all parties concerned, for dealing with mineral leases in Cornwall and Devonshire, such as the bill which was introduced into the House of Commons by Sir John St. Aubyn in 1886.

VIII.—We consider that your Majesty's Commissioners of Woods and Forests have dealt with the Crown rights to gold in Wales as liberally as was consistent with their duty.

IX.—We are of opinion that some measures should be taken to prevent the serious obstacles to the development of the minerals in Ireland, likely to arise from the multiplication of small proprietary rights resulting from recent land legislation.

X.—As regards way-leaves, we are of opinion that owners of mineral property, unreasonably debarred from obtaining access to the nearest or most convenient public railway, canal, or port on fair terms, or from obtaining underground easements on fair terms, ought not to be left without remedy, and we have made certain suggestions with that object.

XI.—We suggest that the Department of Mines in the Home Office might be re-organized and extended, with such additional statutory powers as may be necessary for the purpose of collecting and publishing accurate information with regard to mines and minerals.*

* Final Report, page 79

TABLE II.

Date of Experiment	April 29th, 1893.	May 11th, 1893.				May 15th, 1893.				Average of Experiments, 2 to 9.
No. of Experiment..	1.	2.	3.	4.	5.	6.	7.	8.	9.	
Condition of mine	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.
Revolutions of fan per minute	19·87	39·97	39·87	39·63	39·90	39·52	39·89	39·72	39·95	39·806
Revolutions of anemometer per minute... ...	242	448	443	446·5	454	460	458	455	461	—
Velocity of air in feet per minute	272	478	473	476·5	484	490	488	485	491	—
Volume of air in drift in cubic feet per minute	49,686	86,996	86,086	86,723	88,088	89,180	88,816	88,270	89,362	87,940
Water-gauge in drift in inches	0·29	1·13	1·133	1·12	1·103	1·06	1·06	1·06	1·06	1·09
Temperatures in air, wet bulb	—	54¼	53	52	51½	46⅓	46½	46½	46½	—
„ „ dry bulb	45½	62½	61½	59	58¼	47½	47¼	47⅓	47¼	—
„ in drift, wet bulb	—	60	59¾	59¼	59¼	60	60½	59⅓	59⅓	—
„ „ dry bulb	60½	60	60	59½	59½	60	60½	59½	59¾	—
Boiler pressure, pounds per square inch... ...	60	99	100	100	99	99	100	99	100	—
Mean pressure of indicator-diagrams in pounds per square inch	9·04	20·26	20·565	20·28	20·224	21·09	21·00	21·17	21·21	—
Weight of an inch of water in pounds	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2
Horse-power in air...	2·27	15·49	15·36	15·305	15·31	14·89	14·83	14·74	14·92	15·105
Indicated horse-power of engine	6·463	29·08	29·44	28·86	28·97	29·86	30·08	30·19	30·42	29·612
Efficiency, per cent.	35·12	53·26	52·17	53·03	52·84	49·80	49·30	48·82	49·05	51·02

TABLE III.

Date of Experiment	May 17th, 1893.				May 25th, 1893.				Average of Experiments, 10 to 17.	May 14th, 1893.		
No. of Experiment	10.	11.	12.	13.	14.	15.	16.	17.		18.	19.	20.
Condition of mine	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	Ordnry.	*	*	*
Revolutions of fan per minute	60·83	60·82	60·68	61·00	59·96	60·42	60·08	59·72	60·44	60·00	59·88	67
Revolutions of anemometer per minute	746	734	723	734	694	697·5	704·2	694	—	1,330	1,332	—
Velocity of air in ft. per minute	776	764	753	764	724	727·5	734·2	724	—	1,360	1,362	—
Volume of air in drift in cubic feet per minute	141,232	139,048	137,046	139,048	131,768	132,405	133,624	131,768	135,742	247,520	247,884	—
Water-gauge in drift in inches	2·46	2·47	2·46	2·48	2·42	2·44	2·50	2·46	2·46	2·14	2·14	—
Temperatures in air, wet bulb	48	48	48½	48	49½	49¼	48¼	48	—	52	52	—
,, ,, dry bulb	48½	47½	48½	48	54½	54½	52	51½	—	55½	55½	—
,, in drift, wet bulb	—	60	59½	—	58½	58½	58¼	58	—	56	56	—
,, ,, dry bulb	—	60	59½	—	59	59	58¾	58½	—	57½	57½	—
Boiler pressure in lbs. per sq. in.	99	99	98	100	97	97	99	97	—	106	106	—
Mean pressure of indicator diagrams in pounds per sq. in.	45·34	45·04	44·87	45·02	43·428	43·468	43·880	43·203	—	71·32	72·10	86·95
Weight of an in. of water in lbs.	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	5·2	—
Horse-power in air	54·746	54·119	53·124	54·338	50·247	50·907	52·64	51·08	52·65	83·47	83·59	—
Indicated horse-power of engine	99·04	98·37	97·76	98·62	93·505	94·31	94·66	92·65	96·114	153·67	155·08	209·2
Efficiency per cent.	55·27	55·01	54·34	55·09	53·73	53·99	55·61	55·13	54·78	54·32	53·92	—

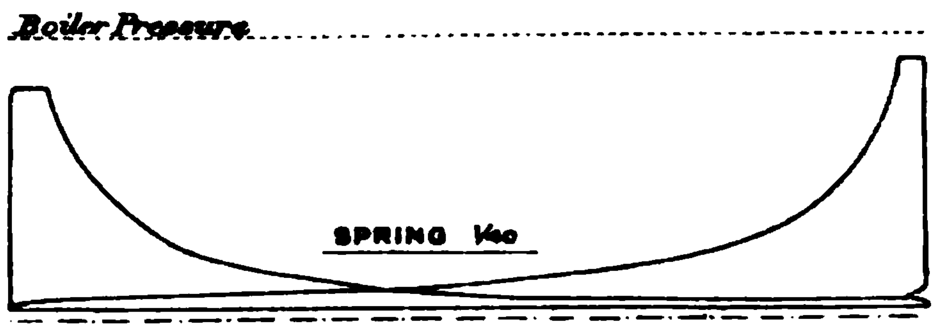
* Separation-doors open.

TABLE IV.

Date of Experiment	May 8th, 1893.	May 9th, 1893.	May 23rd, 1893.	May 29th, 1893.	Average of Four Tests, A, B, C, and D.	May 6th, 1893.	May 10th, 1893.	May 25th, 1893.	Average of Three Tests, E, F, and G.
Experiment	A.	B.	C.	D.		E.	F.	G.	
Duration of test in hours	7½	8¼	8	7¼	7·77	6	8·633	8	7·544
Revolutions of engine per minute	39·91	39·84	39·77	40·20	39·93	60·13	60·18	60·013	60·108
Boiler pressure in pounds per square inch	98	99	99	99	98	96	98	97	96
Mean pressure of indicator diagrams in pounds per square inch	22·39	22·30	20·736	22·116	—	46·556	46·64	43·584	—
Indicated horse-power of engine	32·15	31·97	29·61	31·92	31·41	100·52	101·00	93·925	98·482
Water put into boiler, in pounds	7,938	10,584	8,883	7,938	—	16,065	23,814	21,168	—
Temperature of feed water, degs. Fahr.	128	129	118	135	128	115	141	172	143
Waste water in pounds	172	155	136	150	—	186	177	224	—
Water used by engine and steam jacket in pounds	7,766	10,429	8,747	7,788	8,682	15,879	23,637	20,944	20,153
Water from steam jacket in pounds	401	501½	467	418	—	470·5	562	476	—
Steam jacket water, per cent.	5·16	4·81	5·33	5·37	5·17	2·97	2·37	2·27	2·54
Steam or water used per indicated horse-power per hour, in pounds	32·19	39·54	36·92	33·27	35·57	26·32	27·1	27·87	27·12

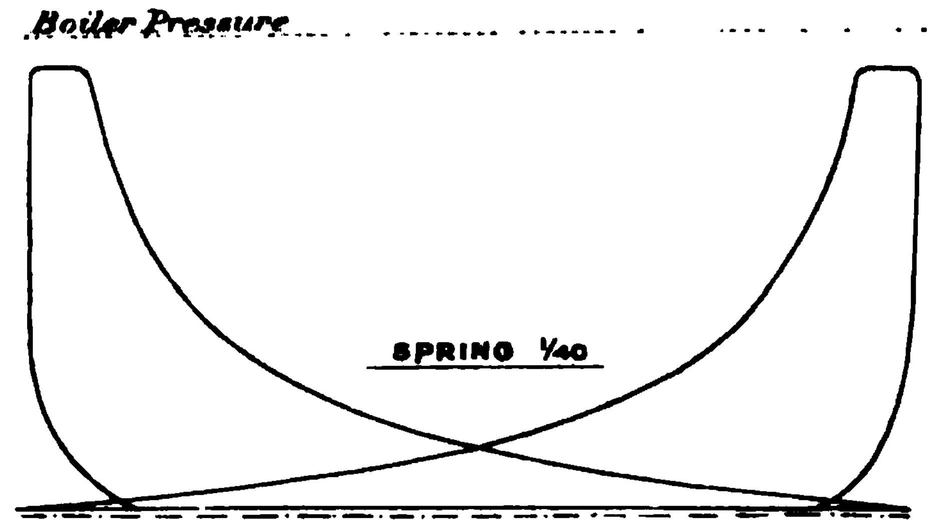
To illustrate Mr C. C. Leach's Paper on "A Corliss-engined Fan at Seghill Colliery."

FIG. I.



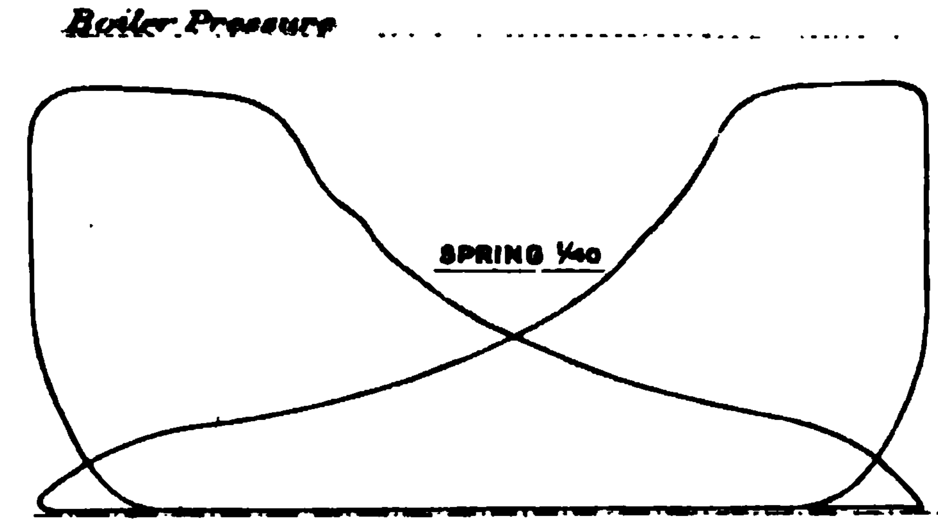
ENGINE RUNNING AT 20 REVOLUTIONS PER MINUTE, AND MINE UNDER ORDINARY CONDITIONS.

FIG. 2.



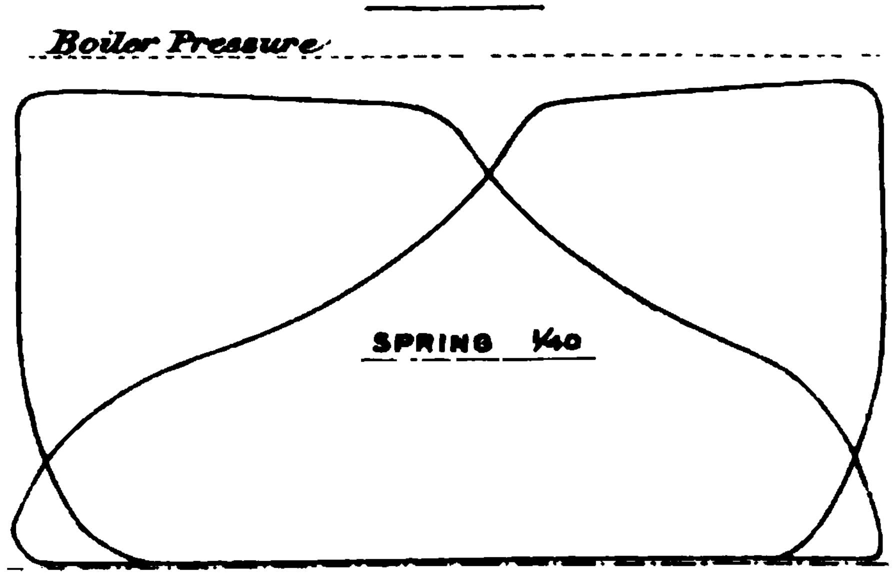
ENGINE RUNNING AT 40 REVOLUTIONS PER MINUTE, AND MINE UNDER ORDINARY CONDITIONS.

FIG. 3.



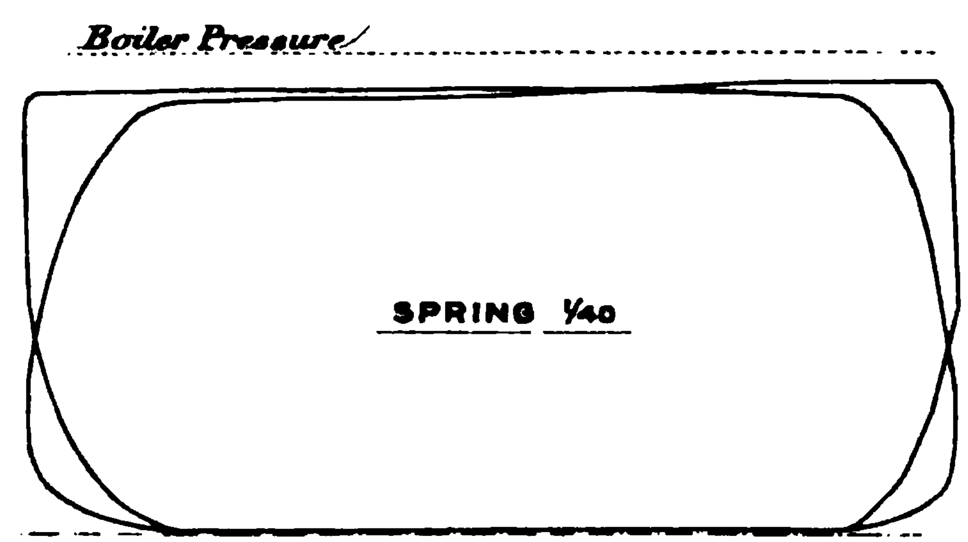
ENGINE RUNNING AT 60 REVOLUTIONS PER MINUTE, AND MINE UNDER ORDINARY CONDITIONS.

FIG. 4.



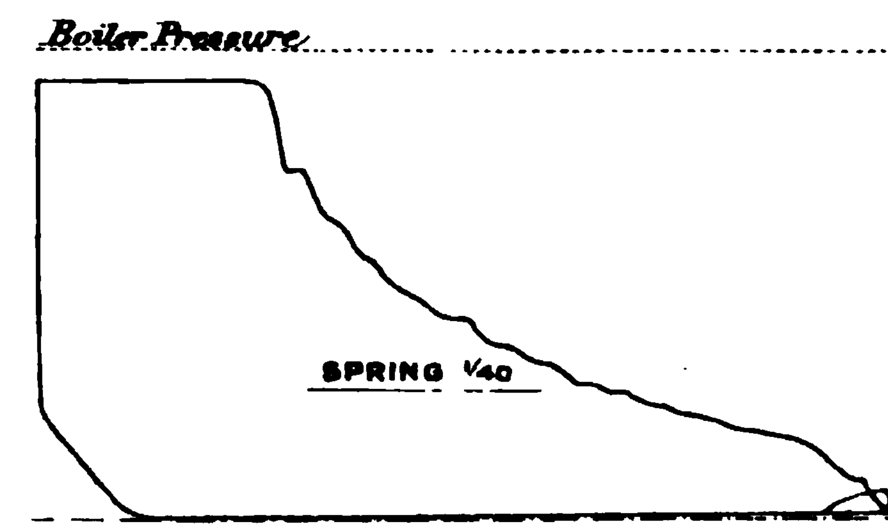
ENGINE RUNNING AT 60 REVOLUTIONS PER MINUTE, AND SEPARATION DOORS OPEN.

FIG. 5.



ENGINE RUNNING AT 67 REVOLUTIONS PER MINUTE, AND SEPARATION DOORS OPEN.

FIG. 6.



ENGINE RUNNING AT 35 REVOLUTIONS PER MINUTE, WITH FRONT STEAM-VALVE DISCONNECTED AND STEAM ADMITTED TO THE BACK END OF CYLINDER ONLY.

THESE INDICATOR DIAGRAMS ARE HALF-SIZE.

TABLE V.—SUMMARY OF EXPERIMENTS.

Revolutions of Fan per Minute.	Useful Effect.	Volume of Air per Minute in the Fan Drift.	Indicated Horse-power of Engine.	Steam or Water used per Indicated Horse-power per Hour. (Including Steam Jacket.) Measured into Boiler.	Accounted for by Diagram Card.	Jacket Water.	Condition of Mine.
	Per Cent.	Cubic Feet.		Pounds.	Pounds.	Per Cent.	
20	35·12	49,686	6·46	—	—	—	Ordinary.
40	51·02	87,940	29·61	35·57	24·34	5·17	"
60	54·78	135,742	96·11	27·12	21·50	2·54	"
60	54·12	247,702	154·35	—	—	—	Separation doors open.
67	—	—	209·20	—	—	—	Separation doors open.

The tests prove great economy of steam, unparalleled regularity of fan revolutions, that there is no wire-drawing, and that the back-pressure is under 1 lb., with great range of power.

It is impossible to have a fan engine with a good margin of power for more air, or less favourable condition of the pit, and have its best economy at usual speeds, but it is probable that this engine running at 80 revolutions (its full speed) with a suitable load would give still better results.

Another advantage of this engine is its small size, only requiring small engine-house and small steam pipes.

In conclusion, the writer acknowledges his indebtedness to Mr. M. Walton Brown for his assistance in calculating the size of the fan, and the power required, and also for his assistance when making the experiments recorded in this paper.

The CHAIRMAN asked if Mr. Leach had tried any experiments without the steam jacket, and whether it was a Waddle fan ?

Mr. COCHRANE said that about 1,300 tons of coal burnt per annum was given as the quantity formerly used by the furnaces, and that the ventilation had been doubled by the use of the fan. Could Mr. Leach tell them what was the present consumption of coal, so that a comparison could be made ? He would also like to ask what additional advantage Mr. Leach expected to obtain by applying a condenser ? Judging from the indicator diagrams the economy would be very considerable. Did the ninety-one squares into which the fan drift was divided each contain the anemometer for 15 minutes, or was that the total time of observation ?

Mr. LEACH said he had tried no experiments without the steam jacket. The fan was of the Waddle type, and took in air at one side only. Fifteen minutes was the total time occupied in measuring the air, and the anemometer was held in each square for about 10 seconds. The boiler, which also supplies steam to the hauling engine, etc., was isolated during the tests, and the small coal actually burnt was weighed. The Lancashire boiler is 8 feet in diameter and 30 feet long, and is about six times too large for the fan engine alone when running at 40 revolutions, and two and a half times too large when running at 60 revolutions per minute. The following table shows the consumption of fuel :—

Fan Revolutions per Minute.	Volume of Air per Minute in Returns.	Duration of Tests.	Fan Engine.		Furnace.	Coals Saved per Annum.
			Small Coal burnt per Annum.	Coal burnt per Indicated Horse Power per Hour.	Small Coal burnt per Annum (calculated).	
	Cubic Feet.	Hours.	Tons.	Pounds.	Tons.	Tons.
40	80,817	31·41	560	4·80	2,804	2,244
60	122,284	22·63	1,437	3·97	9,712	8,275

Very slight advantage would be obtained by using a condenser when running the engine at 40 revolutions per minute (under 100 tons of coal per annum). The condenser was not added because it was wished to start with the engine as simple as possible, and to hold this power of the condenser in reserve.

Mr. W. C. BLACKETT observed that Mr. Leach had measured the quantity of water consumed during these experiments; it would be interesting to know how he had succeeded in measuring this accurately. Could he also give them any information as to the steam jacket? Was it of any use whatever?

Mr. LEACH said the water was pumped from a measured tank into the boiler. The steam jacket was simply intended to keep the cylinder as hot as possible, and to prevent the steam inside the cylinder from being condensed into water.

The CHAIRMAN said it was generally understood that a steam jacket gave an additional economy of about 15 per cent.

Mr. BLACKETT said he failed to see how the use of a larger cooling surface, which the jacket gave, could result in a greater efficiency than the smaller cooling surface of the cylinder alone.

Mr. LEACH said the steam had a temperature of 337 degs. on being admitted to the cylinder at 100 lbs. pressure. When it left the cylinder the temperature was about 212 degs., and the live steam next admitted

had to warm the cylinder again; if they could keep it warm on the outside it saved steam inside, especially in high expansions.

The CHAIRMAN said that engineers were very much divided as to the efficiency of the steam jacket, and during the past few years experiments had been made by members of the Mechanical Institution of Engineers, and the results (which had been published in the Transactions of that Institution), he believed, were favourable to the steam jacket. It had always been stated (whether true or not he did not know) that they gained from 10 to 15 per cent. by the adoption of a steam jacket; the steam lost its heat in getting into the cylinder and the jacket acted as a superheater, giving back the heat lost. He had, for his part, always advocated the use of steam jackets, and had attached them to most of the large engines he had put up.

The CHAIRMAN asked Mr. Leach if he could try some experiments without the steam jacket?

Mr. LEACH—It could be done, but it is a special experiment; and the apparatus has been disconnected.

Mr. M. WALTON BROWN did not know whether any member had ever made tests similar to those recorded by Mr. Leach, in which they had compared the quantity of water or steam used with the indicated horse-power. The only other records he had seen were given in the *Transactions* of the Federated Institution of Mining Engineers.* From the results contained in Mr. Hendy's paper on "Experiments upon a Waddle Fan and a Capell Fan Working on the Same Mine at equal Periphery Speeds, at Teversal Colliery," it might be calculated that with the Waddle fan, 119 lbs., and with the Capell fan, 113 lbs. of water or steam were used per indicated horse-power. Mr. Leach's results were much smaller than these, being practically only 30 lbs. of water per indicated horse-power, showing an economy of about 75 per cent. both in the consumption of coal and the water evaporated.

Mr. T. H. M. STRATTON said the difference pointed out by Mr. Brown between these two sets of observations was so great that one could only remark that evidently Mr. Leach had done well in bringing the subject before them. Many engineers were apt to think that the battle was one of fans, when actually it was not so much the fan itself as the circumstances of the mine, the engine driving the fan, and the pressure of steam applied to that engine. He was afraid to think that they had of late years sat there meeting after meeting and heard it asserted that this or that fan was most efficient. Mr. Leach had started a new hare in stating that the best fan was one which used the least volume of water

* Vol. iv., page 476.

per indicated horse-power, and that it was desirable to ascertain what was the best engine to drive a fan, rather than what was the best fan to exhaust the air out of the mine. Mr. Leach had said to him one day that he could not afford to buy a bad engine. He thought there was a great deal of truth in that remark, and if everybody would look upon steam-using with the view that they could not afford to have a bad engine they would obtain much better results from the fan, and from the winding and hauling engines than they had at present.

Mr. R. F. SPENCE asked what was the temperature of the feed-water?

Mr. LEACH replied that it was 150 degs., and the exhaust steam from the engine was used to heat the feed-water.

Mr. HENRY WHITE asked if the same class of coal was burned in each case?

Mr. LEACH—Yes, small coal.

The CHAIRMAN said as no further remarks were offered, he proposed that a vote of thanks be given to Mr. Leach for his very valuable addition to the literature of fan ventilation. It appeared quite clear that high economy could be attained in fan ventilation by the use of economical engines. It was certain that an engine of high or triple-expansion would give a better result than a single cylinder with steam admitted during full length of the stroke. The paper showed the advantage of using such engines and boilers as economized steam and fuel.

Mr. G. B. FORSTER seconded the motion, which was carried with acclamation.

Mr. LEACH, in acknowledging the vote of thanks, said he would be very glad to show the engine and fan to any of the members.

DISCUSSION UPON MR. R. T. MOORE'S PAPER UPON "JOSEPH MOORE'S HYDRAULIC PUMPING ARRANGEMENT."*

Mr. C. J. MURTON asked the author if it were possible to increase the speed of the engine in the same way as the speed of ordinary pumping engines could be increased in cases of emergency, as it seemed to him that any increase of speed would, owing to the restriction met with in the power pipes, be attended with a great loss of efficiency?

The following paper by Mr. Edward Halse on "The Occurrence of Mercury at Quindiú, Tolima, U.S. Colombia," was taken as read:—

* *Trans. Fed. Inst.*, vol. iv., page 331.

NOTE ON THE OCCURRENCE OF MERCURY AT QUINDIÚ, TOLIMA, U.S. COLOMBIA.

BY EDWARD HALSE.

According to Humboldt,* a vein of cinnabar was discovered in 1786 near the pass of Quindiú† by some miners from Sapo, thanks to the patriotic zeal of the botanist Mutis, at whose expense the examination was made.

Recently, Señor Joaquin Campuzano examined the colonial archives and discovered a note of the year 1787, to the effect that six workings had been opened up in the Sierra de Quindiú showing veins of cinnabar.‡

In 1886, diligent search was made for the old mine, with the result that in a few months' time indications of cinnabar were discovered, and subsequently the six levels, referred to in the archives, were laid bare, together with various furnaces and some tools.‡

During a two years' residence in Colombia the writer had an opportunity of examining the mine, and it was found to contain some interesting features.

The mine is situated on the eastern slope of the Central Cordillera (known here as La Sierra del Quindiú) of the Andes, one long day's mule journey (25 miles) west-south-west of Ibagué, and a few hours' ride from Ibagué Viejo. The latter place was situated on a small plateau, but now only a few mounds indicate the site of the old town. In the alluvium filling the ravine or *quebrado* of the river Bermillon (Spanish for vermilion) running at the foot of the plateau, rounded fragments of cinnabar were found mixed with pellets of gold.*

The mine is nearly 10,000 feet (3,000 metres) above sea-level, on the side of a steep and densely timbered mountain. At this altitude it rains for

* *Essai Politique sur le Royaume de la Nouvelle-Espagne*, 1811, vol. 4, pages 117-118. See Spanish edition *Ensayo sobre Nueva-España*, Jalapa, 1870, vol. 2, page 101.

† Often spelt Quindió—but the above spelling is correct, and is that given in Mr. J. Arrowsmith's Map of Colombia, and also by Humboldt.

‡ *Revista de Minas*, Bogotá, 1888, No. 2, page 57.

DR. THE TREASURER IN ACCOUNT WITH THE NORTH OF ENGLAND

FOR THE YEAR ENDING

			£	s.	d.	£	s.	d.
July 23, 1892.								
To Balance at Bankers			448	14	2			
" " in hand			36	18	4			
						485	12	6
" Dividend of 3¾ per cent. on 134 Shares of £20 each in the Institute and Coal Trade Chambers Co., Ltd., for the half-year ending December, 1892			100	10	0			
" " 3¾ for half-year ending June, 1893 ...			100	10	0			
" Interest on Investments with the River Tyne Commissioners			53	12	6			
						254	12	6
To SUBSCRIPTIONS FOR 1892-93 AS FOLLOWS:—								
431 Members ... ... @ £2 2s.			905	2	0			
26 Associate Members ... ... @ £2 2s.			54	12	0			
28 Associates ... ... @ £1 1s.			29	8	0			
21 Students ... ... @ £1 1s.			22	1	0			
56 New Members ... ... @ £2 2s.			117	12	0			
14 " Associate Members ... ... @ £2 2s.			29	8	0			
16 " Associates ... ... @ £1 1s.			16	16	0			
5 " Students ... ... @ £1 1s.			5	5	0			
			1,180	4	0			
To SUBSCRIBING COLLIERIES, VIZ.:—								
Ashington Coal Company	£2	2	0					
Birtley Iron Company	6	6	0					
Bridgewater Trustees	6	6	0					
Marquis of Bute	10	10	0					
Earl of Durham	10	10	0					
Haswell Coal Company	4	4	0					
Hetton Coal Company	10	10	0					
Hutton Henry Coal Company	2	2	0					
Marquess of Londonderry	10	10	0					
North Brancepeth Coal Company ...	2	2	0					
Owners of North Hetton Colliery ...	6	6	0					
Ryhope Coal Company	4	4	0					
Seghill Coal Company	2	2	0					
South Hetton Coal Company	4	4	0					
Stella Coal Company	2	2	0					
Owners of Throckley Colliery	2	2	0					
Victoria Garesfield	2	2	0					
Wearmouth Colliery	4	4	0					
			92	8	0			
" 1 NEW SUBSCRIBING COLLIERY—								
Butterknowle Coal Company	2	2	0					
			2	2	0			
			1,274	14	0			
Less—Subscriptions for current year paid in advance last year			23	2	0			
			1,251	12	0			
To Arrears			208	19	0			
			1,460	11	0			
" Subscriptions paid in advance during current year ...			53	11	0			
						1,514	2	0
" Sale of Publications						42	19	9
						£2,297	6	9

quartz, calcite, and cinnabar—the latter in spots and small strings. In the breast of the level is a flucan running west-north-west, and dipping north 44 degs., showing some cinnabar in the clay of the joint. On the western side of the level near the breast some rather soft beds are exposed with a seam of red-coloured earth 3 or 4 inches thick. The latter, washed in a batea, gave 1½ per cent. of cinnabar.

In the New Almaden mines of California, it was only by carefully following up such colours of mineral that the deposit was developed.*

The Santa Teresa level is to the west of the San Roque, and has been driven for 32 feet. In the end is a vein of very hard quartz, with iron pyrites, calcite, and pretty spots of cinnabar. Below the vein is coloured stuff containing some cinnabar. The beds dip north 25 degs., at the mouth of the level they run about north-west, and dip north-east 39 degs.

Above this level the so-called "veta rica" is seen cropping out at the surface. It contains 2 feet or so of soft decomposed rock with quartz, iron pyrites, oxide of manganese, and cinnabar.

Some little distance above the house, another outcrop of quartz and cinnabar is seen in beds much coloured and spotted with the latter mineral.

Since the writer examined the property, two new levels have been started, but nothing of importance had been discovered down to January 5th, 1890.

A very flat vein of cinnabar was found to crop out just above the New San Blas level running east 30 degs south to west 30 degs. north, dipping south-west 10 degs., and consisting of clay, with bands of quartz impregnated with cinnabar. In the level the rock, dipping south-west 39 degs., consisted of lumps of albitic diorite in felspathic clay containing much iron pyrites.

At the Riveras working, on the other side of the ridge, the rock was dioritic and of the usual strike and dip.

For some depth the rocks in this mine are more or less decomposed to a soft clay; the thickness of the cap varies much: in places the rock is comparatively hard right up to the surface, while elsewhere there exists a cap of soft rock several feet thick.

This so-called alluvial cap is said to have been proved to exist for a length of 5,000 feet (1,500 metres), and a width of 1,300 feet (400 metres), but its value has probably been exaggerated.

* Prof. J. B. Christy, quoted in *Engineering and Mining Journal*, January 5th, 1889, page 10. See also Mr. Becker's monograph. Mr. Coignet says it was by following veinlets of calcite (*Rapport sur les Mines de New Almaden*, 1866, page 11).

Immediately above the house, where an artificial pond (*estanque*) has been cut, the decomposed rock seems to be 15 feet thick. Below it the bed-rock of soft talcose-chloritic schist is seen to trend considerably more to the north than usual. Upon it rests 3 feet of yellow coloured alluvium which gives a little cinnabar in the batea. Above this is red-coloured clay which yielded no cinnabar. The cap tested elsewhere gave sometimes a little cinnabar, and sometimes none at all.

In one place, where the rock is hard at the surface, there is a seam of clay 3 feet thick, which gives some cinnabar in the batea.

The average percentage of cinnabar in the veins and seams examined by the writer was somewhere between one-half and two and a half.

Notwithstanding the fact that the mine could then only be regarded as a prospect—a bold attempt was made to float it in the city of London as a large and proved deposit. Reports were written comparing the mine to the classical Almaden of Spain, and a section was published therewith showing numerous veins of cinnabar (beautifully coloured) traversing the hill from base to summit, a section which one could only compare to those physiological diagrams which illustrate the arterial circulation of the blood.

It is not altogether improbable that a paying deposit occurs farther in the mountain and nearer the large dyke of diorite which is said to penetrate the centre of the hill. But in order to prove this the old Spanish level should be driven on.

At Almaden the cinnabar occurs principally in nearly vertical bands of quartzite or grit, and is comparatively rare in the beds of encasing schist.* Melaphyre is the eruptive rock adjacent to these deposits. Although in one or two places at Quindiú cinnabar is found associated with a quartz-vein or seam, nothing so far has been disclosed approaching to the siliceous cinnabar-impregnated beds of Almaden, so that until something resembling this is discovered the comparison between the two deposits is (to say the least) premature.

For the sake of comparison a table is appended showing the principal known occurrences of cinnabar, compiled mainly from chapter II. of Mr. G. F. Becker's *Geology of the Quicksilver Deposits of the Pacific Slope*.†

The Quindiú deposit may be regarded as impregnations probably intimately connected with the intrusive dyke of diorite. Heated waters bearing double sulphides of iron and mercury in solution have probably made their

* Mr. H. Kuss, *Mémoire sur les Mines et Usines d'Almaden*, *Ann. des Mines*, 1878, page 29.

† U.S. Geological Survey, monograph XIII.

way up and along this disturbance, and, then passing down the bedding-planes of the softer schists, have impregnated certain beds, occasionally filling joints and fissures therein. The reason why they have scarcely penetrated the hard chloritic beds is probably on account of the want of porosity of the latter.

Mr. Becker says: "The mineral associations in which cinnabar is found seems to show conclusively that it has been deposited from solution." The deposits at Quindiú appear to be no exception to this rule. That author further says: "A very large part of the known deposits of cinnabar are extremely similar in character, a fact which seems indicative of a similar origin. It is certain that some of the deposits are due to precipitation from hot volcanic springs, and it may fairly be inferred that many of them were formed in this manner."

COMPARATIVE TABLE OF CINNABAR DEPOSITS.

Locality.	Rock.	Nature of Deposit.	Associations.	Geological Age of Rock.	Eruptive Rocks in Vicinity.	Authority.	Remarks.
EUROPE. *Spain.*							
Mieres ...	Breccia of sandstone and schist.	Filling cracks and interstitial cavities; sometimes as impregnations.	Pyrites, mispickel and realgar.	Carboniferous.	......	J. G. Klemm	......
Almaden ...	Schists, limestone, quartzite and sandstone.	Veins or vein-like impregnations.	Native mercury, iron pyrites and chalcopyrite in small quantities; with quartz, a little heavy spar, and spots of bituminous matter.	Silurian...	Melaphyre	De Prado, Kuss, Becker, etc.	Mercury, 8·3 per cent. The veins follow, but sometimes cut across the stratification. The richness increases in depth.
Granada ...	Talcose schists	Veins	Grey copper, sulphide of nickel and cobalt, and oxides of iron.	Triassic ...	......	Guillemin-Tarayre.	......
Sierra de Montenegro.	Slates ...	Vein	......	Silurian ?	......	A. Heckmanns.	......
La Creu ...	Sandstone ...	Veinlets...	Iron pyrites, quartz and carbonates.	......	......	G. F. Becker	......
Germany. Rhenish Bavaria or Palatinate.	Limestone and sandstone.	Veins and impregnations	Iron pyrites, copper ores, lead and silver minerals (rare), calcite, quartz, chalcedony, heavy spar and bituminous matter.	Carboniferous.	Melaphyre	H. von Dechen.	Richest at top, gave out in depth. Cinnabar found replacing organic remains.

COMPARATIVE TABLE OF CINNABAR DEPOSITS.—*Continued.*

Locality.	Rock.	Nature of Deposit.	Associations.	Geological Age of Rock.	Eruptive Rocks in Vicinity.	Authority.	Remarks.
Austria.							
Idria	Schists, sandstones, dolomitic limestones and breccia.	In fissures, as bed-like veins, filling cracks, and as impregnations and stockworks.	Native mercury (small quantity), iron pyrites, quartz, calcite, dolomite, fluor (rare), idrialite, and anthracite in compact masses.	Triassic ...	Trachyte	M. von Lipold	Mercury 1·4 per cent. Fissures sometimes cut across and sometimes follow the planes of bedding. Richness increases in depth.
Horowitz (Bohemia).	Schists ...	In cracks at right angles to the bedding.	Iron pyrites, heavy spar and calcite.	......	......	Von Cotta...	Bed of hæmatite occurs here.
Thihuthal (Hungary).	Argillaceous schist.	Veins, in streaks and bunches.	Galena, blende (small quantity) calcite, dolomite, and country rock.	......	Lava ...	Von Cotta...	Occurs at contact of dyke of lava with much-altered schists.
Italy.							
Agordo ...	Quartz-porphyry, sandstones, shales, graphitic slate, limestone and conglomerate.	Impregnations in porphyry and sandstone, and as stringers in shales. Great mass of it in the conglomerate as small grains and stringers.	Iron pyrites, mica, gypsum, calcite and quartz	Triassic ...	Porphyry	G. von Rath	0·2 to 1 per cent. of quicksilver ordinarily, but up to 24 per cent. At and near contact of porphyry and sedimentary rocks.
Mount Amiata	Limestones and siliceous beds.	Small irregular veins and impregnations in clay.	In veins with "neri"* and native quicksilver, in clay with iron pyrites, calcite and gypsum.	Eocene ...	Trachyte	B. Lotti, P. de Ferrari, and — Primat.	Found as masses and veinlets in clay with veins of calcite. Probably of post-Tertiary age.
Selvena ...	Marl	Impregnations	Calcite	......	Trachyte	A. d'Achiardi	Calcite in stringers spotted with cinnabar.

* Sub-sulphide of mercury (Hg_2S).

COMPARATIVE TABLE OF CINNABAR DEPOSITS.—*Continued.*

Locality.	Rock.	Nature of Deposit.	Associations.	Geological Age of Rock.	Eruptive Rocks in Vicinity.	Authority.	Remarks.
Corsica. Cape Corso ...	Pegmatite, serpentine, euphotide schists and serpentiferous limestones.	Fissures in the rocks ...	Stibnite, iron pyrites, blende, sulphur and quartz.	......	......	D. Hollande	......
Servia. Mount Avala	Serpentine (alteration product of an enstatite-olivine rock).	Vein-like, in seams and stringers of quartz and heavy spar which intersect the vein-matter in all directions; and as impregnations, and replacement (?).	Native mercury, calomel (in small quantities), chrome iron, iron pyrites, millerite, galena (rare), chalcedony, quartz, calcite, dolomite, barytes and iron oxides.	......	......	A. von Groddeck.	......
Turkey in Europe. Serajevo ...	Schists and limestones.	Veins and beds ...	Iron pyrites, blende, traces of gold, calcite, dolomite, and country rock.	......	......	A. Conrad ...	Veins nearly vertical and sometimes several inches thick.
Russia. Bachmut ...	Sandstone overlain by clay-slate.	Impregnations and in cracks.	Galena	Carboniferous.	......	Tschermak	......
ASIA. *Siberia.* Nertschinsk ...	Limestone ...	Little veins and bunches	Calcite and quartz ...	......	Granite ...	Von Kokscharow.	......
Japan. Hirado ...	Sandstone ...	Small fissures and seams	......	Carboniferous.	......	H. S. Monroe	......

COMPARATIVE TABLE OF CINNABAR DEPOSITS.—*Continued.*

Locality.	Rock.	Nature of Deposit.	Associations.	Geological Age of Rock.	Eruptive Rocks in Vicinity.	Authority.	Remarks.
Borneo.							
Tagora ...	Metamorphosed shales and sandstones.	Irregular, and in vein-like developments.	Iron pyrites, stibnite (rare), calcite and heavy spar.	......	......	......	In slate—more rarely in sandstone.
AFRICA. *Algeria.*							
Palestro ...	Limestone ...	Veins	Decomposed blende and galena.	Upper Cretaceous.	......	A. Heckmanns.	Ores contain silver and mercury (sometimes 3½ per cent.).
NORTH AMERICA.							
California, U.S.	Slates (mostly metamorphosed) granite, ancient porphyry, andesites, rhyolite, basalt.	Impregnations, or as beds and deposits, in crevices, as stockworks "chambered veins" (Becker).	Native mercury (rare), iron pyrites, quartz, chalcedony, calcite, dolomite, pearl spar, chlorite and bituminous matter.	Cretaceous	Serpentine & trachyte.	G. F. Becker — Coignet.	Mercury 1–3 per cent. Probably deposited from hot sulphur springs in post-Pliocene times.
Mexico.							
Calzones ...	Pitchstone-porphyry.	Vein (S. Juan de la Chica).	Native mercury, etc. ...	......	......	A. von Humboldt.	Walls impregnated with cinnabar and quicksilver.
Durasno ...	Porphyry ...	Layers, resting on porphyry.	Native mercury, etc. ...	......	......	A. von Humboldt.	Surmounted by beds of shaly clay containing fossil wood and coal.
Guadalcázar	Limestone ...	Layers and stockworks.	Guadalcázarite, native sulphur, calcite and fluorspar.	Cretaceous?	Granite & porphyry.	Ramirez ...	Deposits generally separated from country by gypsum.
Guadalcázar	Granite ...	......	Pyrites and galena ...	......	......	A. Nöggerath	......

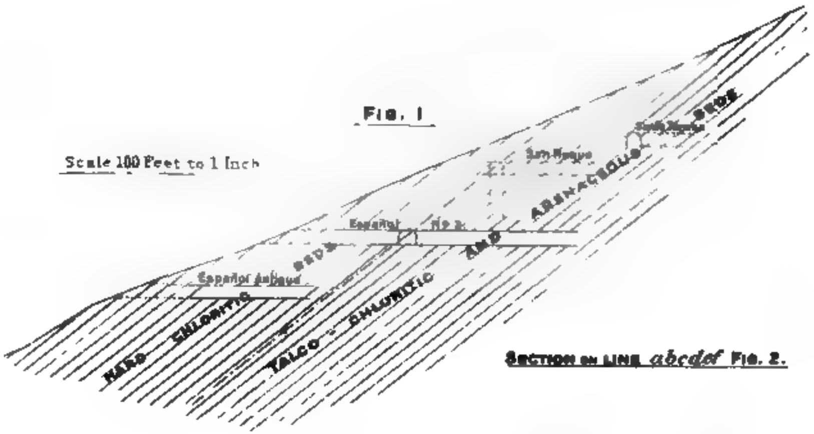
COMPARATIVE TABLE OF CINNABAR DEPOSITS.—*Continued.*

Locality.	Rock.	Nature of Deposit.	Associations.	Geological Age of Rock.	Eruptive Rocks in Vicinity.	Authority.	Remarks.
Huitzuco ...	Metamorphic slates and limestones.	Pockets, layers and veins	Stibnite, cinnabar, as pseudomorphs after stibnite, quartz, and gypsum.	......	Serpentine, etc.	T. L. Laguerenne.	The ordinary ore is livingstonite.
Chilapa ...	Metamorphic slate.	Vein	Quartz and iron oxides	......	......	G. F. Becker	Fragments of country in it—ore impregnates entire width.
SOUTH AMERICA *U.S. Colombia.* Quindiú, Ibague.	Talco-chloritic, arenaceous and aluminous schists.	Impregnations and veinlets.	Iron pyrites, oxides of iron and manganese, quartz, calcite, clay, etc.	Silurian?	Diorite ...	......	......
Ecuador. Azogue ...	Ancient sandstones.	Veins	......	......	......	G. F. Becker	......
Peru. Chonta ...	Sandstone ...	Bed of clay, sand, iron pyrites and cinnabar.	Iron pyrites, clay and sand.	Early Palæozoic.	......	Bugdoll ...	......
Ancachs ...	.. ...	Veins	Galena, blende, iron pyrites, and grey copper.	......	......	M. du Châtenet.	......
Yauli... ...	Schists and sandstones.	Seams and pockets in quartz-veins.	Iron pyrites	......	......	Bugdoll ...	Hot sulphur springs close by deposit sulphur at the surface.
Huancavelica (Santa Barbara mine).	Sandstone and clay-slate.	Bed-impregnations, stringers and stockworks.	Iron pyrites, mispickel, realgar, galena, calcite and barytes.	Jurassic (Crosnier).	Porphyries, trachytic, lavas and granite.	Humboldt, E. de Rivero.	Hot springs near.

To illustrate Mr Edward Halse's "Note on the Occurrence of Mercury at Quindiú U.S. Colombia."

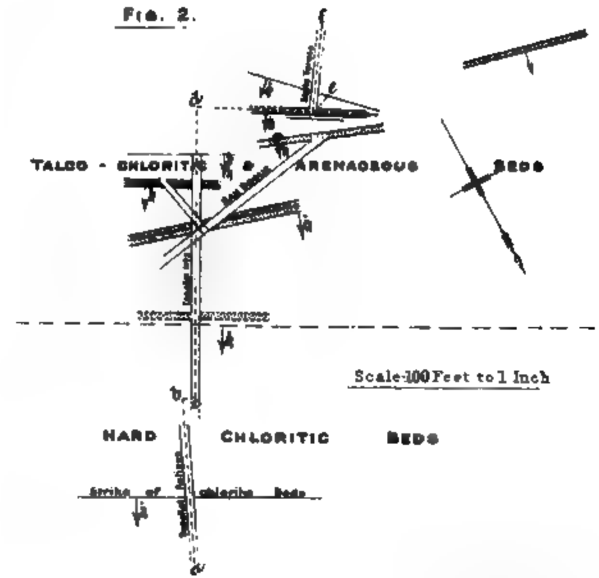
Fig. 1

Scale 100 Feet to 1 Inch



Section on line abcdef Fig. 2.

Fig. 2.



Scale 100 Feet to 1 Inch

Reference to Fig. 2.

Cinnabar Impregnated Veins or Beds

Horizontal Scale 24 ...
Vertical Scale ...

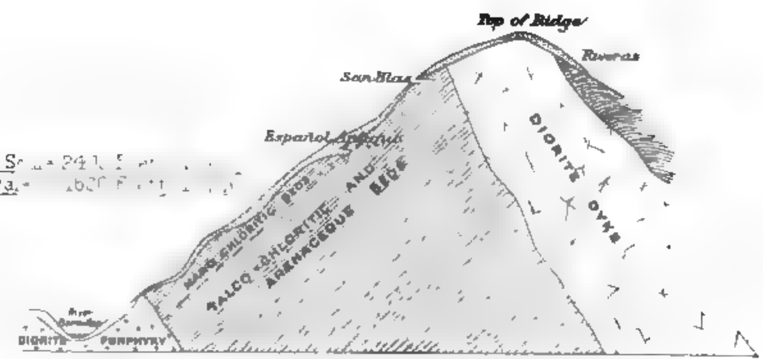


Fig. 3.

THE CHOICE OF COARSE AND FINE-CRUSHING MACHINERY AND PROCESSES OF ORE TREATMENT.*

BY A. G. CHARLETON.

PART IV.—GOLD.

FREE-MILLING AND GRINDING-MILLING.†

The cost of plant and of treatment of this character, in various parts of the world must now be considered, and to do so the author has drawn up Table I. hereto appended, which gives particulars of the plant and the approximate cost, as far as it can be estimated, of various well-known mills, gathered from such information as can be obtained on the subject.

Turning to Table I., it will be remarked that the cost of plant per stamp-head is least in Wales and America and greatest in Queensland, Australia, though it might cost a good deal more in out-of-the-way parts of Africa, South America, or Asia. It is stated that some of the earlier Johannesburg batteries cost £800 per stamp,‡ and the old Eureka mill, in California, cost £500 per stamp.

The low cost of the Welsh§ and American mills is partly explained by the fact that there are no heavy duties and comparatively slight freight charges to pay, which are a heavy item in other places, such as Queensland. The chief reasons, however, are that the former mills dispense with the grinding, tailings, and other plant that adds considerably to the cost of the Australian batteries, and that the prices of timber, lumber, and supplies are relatively very large in the Colonies.

For example:—Lumber in California costs about 75s. per 1,000 B.M., and in Queensland, Oregon pine ranging in size from 3 inches by 2 inches up to 9 inches by 9 inches, cost about 18s. 6d. to 21s. per 100 B.M. in 1887-8. Oregon lumber (imported) ranging in size from 8 inches by 8 inches up to 12 inches by 12 inches‖—cost about 1s. 6d. to 2s. 9d. per lineal foot in 1887-8. Redwood boards (well-seasoned) up to 18 inches in width, cost about 26s. to 28s. per 100 B.M. in 1887-8.

* *Trans. Fed. Inst.*, vol. iv., pages 233 and 351, and vol. v., page 271.

† For the treatment of gold ores.

‡ *Mining Journal*, August 27, 1891, page 977.

§ The lower wages-rates, freight-rates, and price of materials in Wales explains the difference which exists between the Welsh and the American costs.

‖ In sticks, 36 to 40 feet in length.

TABLE I.

SHOWING THE CHARACTER AND APPROXIMATE COST OF FREE-MILLING AND GRINDING-MILLING PLANT IN DIFFERENT LOCALITIES.

Locality, District, and Name of Mill or Company.	Nature of Mill Site.	Character of Process.	Water or Steam Power.	Rock Breakers.	Stamps.	Weight of Stamps.	Automatic Feeders.	Number and Kind of Concentrators.	Pans.	Settlers.	Other Machinery.	Approximate Cost of Milling Plant and Mill Buildings.	Cost of Accessory Plant.	Cost per Stamp.	Remarks.
						Lbs.						£	£	£	
Wales— Dolgelly— New Morgan ..	*a*	Battery amalgamation and plates with ripples.	120 H.P. turbine & 125 H.P. eng.	2	40	850	8	Embrey pattern concentrs. used in old mill; not now employed.	....	..	..	8,500*b*	..	212	10 stamps in a battery, with pulley in the middle of the cam shaft. 4½ tons of coal burnt per day.
Italy— Pestarena— Pestarena	..	....	Water power..	1	..	*c*	..	Inclined tables	....	..	*d*	....	..	..	......
India— Wynaad— Indian Consolidated (Phœnix)	*e*	Free gold in battery, and plates, ripples, and pans.	Turbine and engine.	..	20	850	..	4 end-blow tables.	7 Wheelers ..	6	*f*	....	..	..	There are six Wheelers and four Hungarian mills in reserve.
Transvaal (So. Africa), Johannesburg— Jumpers	*e*	Free gold in battery and plates outside.	Comp. engine, 100 H.P.	4	100	780	..	20 Frues, 4 shaking tables, 2 Buddles.	2 Wheelers, 1 Berdan.	1	*r*	45,395	..	454	*v*; *i* 240 × 60; 550 tons of coal burnt per month.
Dakota (U.S.A.)— Deadwood Gulch— Father de Smet ..	*g*	Inside & outside plates and mercury traps and sluice boxes.	Engine with Meyer cut-off (20 × 42).	4	80	758	16	Blankets ..	2 clean-up ..	1	*p*	20,338	653	254	*h*; *i* 68 × 60 *j*; 11 cords of wood per day.
Lead City— Highland	*g*	Do. ..	Eng. 350 H.P., Corliss.	6*k*	120	850	24	Blankets ..	2 clean-up ..	1	*p*	51,042	..	425	*l*; *i* 100 × 80; 14 cords of wood per day.
Homestake	*g*	Do. ..	Eng. 155 H.P., aut. cut-off.	5	80	850	16	Blankets ..	2 clean-up ..	1	*p*	....	..	..	*l*; *i* 100 × 80; 11 cords of wood per day.
Golden Star ..	*g*	Do. ..	Eng. 300 H.P. Harris-Corliss.	6	120	850	4	Blankets ..	2 clean-up ..	1	*p*	....	..	..	*l*; *i* 120 × 88½; 14 cords of wood per day.

TABLE I.—*Continued.*

Locality, District, and Name of Mill or Company.	Nature of Mill Site.	Character of Process.	Water or Steam Power.	Rock Breakers.	Stamps.	Weight of Stamps.	Automatic Feeders.	Number and Kind of Concentrators.	Pans.	Settlers.	Other Machinery.	Approximate Cost of Milling Plant and Mill Buildings.	Cost of Accessory Plant.	Cost per Stamp.	Remarks.
						Lbs.						£	£	£	
Alaska (U.S.A.)— Douglas Island— Alaska-Treadwell ..	*g*	Inside & outside plates and mercury traps and sluice boxes.	6 ft. Knight and 6 ft. Pelton.	6	240	900	48	96 Frues ..	....	..	..	....	..	..	Concentrates chlorinated.
California (U.S.A.)— Plumas County— Plumas-Eureka ..	*m*	Inside & outside plates & silver sluices.	8 ft. Knight and 75 H.P. engine.	3	60	850	12	20 Hendys, 5 Pattons, 3 Duncans.	2 Patton pans, 1 cln.-up barrel, & 1 batea.	2	..	10,417	..	174	Tailings are ground in 30 arrastras and concentrates chlorinated.
Nevada Co. North S[illegible]	*g*	Do. ..	6 ft. Pelton, 4 ft. do., & engine.	2	30	850	6	12 Triumphs ..	1 clean-up, 1 barl., 1 batea.	..	..	....	..	..	......
North Queensland— Charters Towers— Day Dawn Blk. (Burdekin) ..	*m*	Free gold in battery and plates and pans.	100 H.P. eng.	3	60	800	12	24 Frues, 18 Br. & Stansfield.	2 Berdans, 24 Wheelers.	12	..	52,146*n*	..	869	......
Day Dawn P.C. (Excelsior)	*e*	Do. ..	132 H.P. eng.	1	40	896	..	8 Brn. & Stans.	38 Ber, 16 Wh.	8	..	50,000*o*	..	1,250	......
Bonnie Dundee (Plants)	*g*	Do. ..	45 H.P. eng.	..	15	896	..	6 Brn. & Stans.	1 Ber., 11 Wh.	7	..	16,000*o*	..	1,066	......
Defiance	*e*	Do. ..	40 H.P. eng.	..	15*q*	800	..	2 Buddles ..	2 Wh., 24 Ber.	1	..	12,000*q*	..	800	With machinery since added, will probably come to about £1,100.
New Queen	*e*	Do. ..	68 H.P. en. with comp. cylrs. and var. expn. gear.	..	25	800	..	2 Buddles, 2 Br. & Stans., 5 end-blow tables.	39 Ber., 2 Wh. ..	3	..	20,000*o*	..	800	......
Rishton— Disraeli	*m*	Do. .	50 H.P. engines	1	20	760	4	8 Frues ..	8 Ber., 4 Wh. *s*	2	..	20,000*ot*	1,753*u*	1,000	*v*; 4 132 × 50*j*.
Etheridge— Durham and Lord Byron	..	....	82 H.P. engines	1	20	900	..	2 Frues, 4 Br. & Stansfield.	10 Berdans, 8 Wheelers.	2	..	35,000*o*	..	1,750	Freight and labour are much more expensive than in the Charters Towers district.
Cumberland ..	..	....	92 H.P. engines	..	30	900	..	4 Frues, 4 Br. & Stansfield.	3 Berdans, 20 Wheelers.	3	..	35,000*o*	..	1,166	

TABLE I.—*Continued.*

a Laid out in steps with considerable fall, involving about 2,000 cubic yards of cutting in decomposed granite.
b As stated by Messrs. Fraser & Chalmers, who supplied the machinery.
c One pair of rolls, 20 inches × 13 inches.
d Frankfort mill.
e Slight fall.
f 7 Hungarian mills.
g Slightly graded.
h Batteries face to face in two rows, with tables in middle.
i Dimensions of mill building.
j Exclusive of engine-room.
k No. 5 Blake.
l Batteries back to back in two rows.
m Graded.
n Report of the Company, July 22nd, 1890.
o Report Department of Mines, Queensland Government, 1889.
p Grizzlies, boilers, etc.
q Report Department of Mines, 1879. (5 stamps, 3 settlers, 2 Brown & Stansfield concentrators, 2 percussion tables, 24 Berdans, and 2 Wheelers have been added since.)
r 1 Tangye double 10 inches cylinder geared pump, capable of pumping 35,000 gallons per hour.
s Large wooden-sided combination pans, 5 feet diameter.
t This sum includes machinery, grading, timber, and erection of building, fittings and hardware, and freight and duty; also a full stock of tools and supplies for twelve months.
u Published Report of Mr. C. P. Purinton, August 15th, 1887.
v Batteries in line.

"Charters Towers," and "Rishton" are within the Charters Towers gold-field.

The figures in the column of "Cost per Stamp" go to show that the more modern English mills, like the New Queen, Disraeli, and Day Dawn block, have been built cheaper than the mills locally erected previously in the same district. The Burdekin mill, which is an extremely fine piece of work, was built by a Maryborough (Queensland) engineer.

Hardwood boards, of different widths and thicknesses, cost about 23s. to 25s. per 100 B.M. in 1887-8. Kauri pine flooring, T. G. boards of ordinary width, cost about 30s. to 32s. per 100 B.M. in 1887-8. Cordwood costs 18s. to 22s. per cord.

According to the Queensland Government returns (from which the particulars given in Table I. are taken) another point to be noted is that the cost of some of the older Charters Towers batteries, like the Excelsior plant, seems to have been considerably in excess* of that of the newer mills, while even among these latter there are considerable variations of cost.

In this connexion the author would like to draw attention to several points which invariably affect the capital expenditure on any two different mills, and it is therefore of the first importance both to the mill-wright and the mill owner to make due allowance for them in any estimates made beforehand.

The prime cost of a mill, in fact, depends entirely on a variety of conditions:—

* This is no doubt partly owing to the higher cost of wages and freight in the early days of the field (everything having to be carted from Townsville on the coast), but, on the other hand, there was no duty to pay, and the price of bush timber was no doubt lower than it was five years ago.

(1) The size of the mill in regard to the tonnage of ore it is designed to handle.

(2) The general nature of the machinery and the mill site.

(3) The internal details of the building (in grouping and placing various machines together), and the choice of materials used in its construction.

(4) The distance the machinery and appliances composing the plant have to be transported from the place of manufacture, and the ease or difficulty of delivering them at the site of the works.

(5) The cost of the machinery at the foundry.

(6) The duties and commissions paid upon it.

(7) The local cost of labour and of timber, and other structural materials (purchased on the spot or elsewhere) delivered.

(8) The efficiency of the labour employed in their erection, and the time the works are under construction; which is contingent more or less on the willingness and ability of a company to provide for a heavy outlay covering a short period, or preferring payments distributed over a certain length of time.

To illustrate what is meant, the author will take two Queensland batteries with which he has been personally connected, the New Queen and the Disraeli.

The New Queen mill was designed and built on the best Australian plans, under the superintendence of Mr. Geo. Cavey; the erection of the machinery being entrusted to a first-rate English millwright and machinist, Mr. R. Robinson; and the battery has very justly earned the reputation of being one of the finest of its class on the Charters Towers field.

The Disraeli battery, on the other hand, was designed by Mr. J. Deby, of London, on American lines (the minor details and design of the building being left to the author's discretion), and it was erected under his supervision and that of his assistant, Mr. H. L. Lawrence; Mr. Wm. Reed, a most excellent English mechanic from the Sandycroft foundry (which supplied most of the machinery)* erecting everything in running order to plans under his orders.

Now, if we take the actual difference of cost per stamp in the New Queen mill and in the Disraeli, as shown by Table I., we find that the

* Messrs. Fraser & Chalmers furnished the Frue vanners and Messrs. Langland of Melbourne, the extra berdans.

latter plant (erected) apparently cost in proportion about £4,000 more than the New Queen battery, and it is a matter of interest to learn the cause of this discrepancy, of which the author can offer several explanations bearing on the points before mentioned.

Before referring to these, however, the author should point out that the figures given in Table I. as the cost of the Rishton mill are in reality fully £1,000 in excess of the actual sum expended, which should be £19,000, reducing the difference to £3,000. Further, the £19,000 in question includes the cost of a tram line, an expensive pumping station, and tailings-flume (the former to pump water from, and the latter to carry the tailings half-a-mile to, the river). These items do not enter into the cost of the Queen battery. Deducting their cost (according to figures given in a report by Mr. C. P. Purinton, published by the Company, Aug. 15th, 1887) we would have left (£19,000 – £1,605 18s. =) £17,394 2s., or an actual difference in cost of only £1,394 2s. between the two batteries. If, further, the cost of the reservoir in addition to the other outside works be subtracted, it would make the actual cost of the Rishton battery itself £17,246 13s. 6d., or £862 6s. 8d. per stamp, which is what doubtless it actually cost, viz., £8,146 spent on mill-building, construction, grading, and foundations, and the balance of £9,100 on machinery, freight, duty, etc. If a comparison were instituted on this basis it would make the difference in cost between the two mills only £62 6s. 8d. per stamp, or £1,246 13s. 6d. in total. We will assume, however, a supposed difference of £3,000 for the sake of illustrating a case in which this would be actually amply justified.

1. By the relative difference in the size of the two plants.
2. By the difference in the general nature of the machinery composing the two plants, and of their respective sites, which necessitated extra fittings and provisions, which could be dispensed with in the one case but not in the other. Such, for instance, as the cost of heavy framing and spacious bins,* required for the rock-breaker and automatic feeders of the Disraeli, and the extra strong framework needed for the combination-pans and large settlers, as compared with the small ordinary iron-wheelers, berdans, and settling-pans used at Charters Towers. To this may likewise be added

* In this connexion, it is a point worth noting that the planking of ore-bins are best laid on joists resting across the inclined timbers of the framework. The sheathing will then run lengthways down the bin and not across it; if double planked, the joints should be "broken" by covering the lower ones with the top boards.

the extra space taken up in the Rishton mill by the vanners,* which require a solidly and evenly boarded floor, and the fact that in a mill like the Disraeli, provision must of necessity be made to protect the superstructure as far as possible from the attacks of white ants, by bedding the mud-sills of the building on masonry, which is not such a necessary object where a rough stick can be put in or taken out without any great difficulty.

3. By the arrangement of the machinery and consequent difference of design of the internal details of the buildings. The Disraeli battery, being built in steps and storeys, requiring heavy grading, faced with retaining walls of suitable strength, and a massive framing of squared-timber† to support the load of the building and machinery, so as to provide sufficient fall for the ore to descend by gravity, with as little handling as possible, through the mill.

   The New Queen, on the other hand, like most of the other Charters Towers batteries (except the Burdekin and Plants), possessing such slight fall as to allow of the use of ordinary round timber (barked, but otherwise untrimmed) in the construction of the buildings, and requiring no expensive foundations, except for the mortar-blocks of the stamps themselves.

4. By extra freight; Rishton, where the Disraeli battery was located, being 22 miles from the railway terminus (which is at Charters Towers itself), so that an additional charge of £2 to £2 5s. a ton can be reckoned on all material used, representing a by no means insignificant items in the sum total.

Table II. gives the cost of treatment in a tabulated form at several of the mills, which have been referred to in Table I., and will be found useful for purposes of comparison.

* The cost of adding 24 vanners to the Montana Company's mill, at Marysville, is stated to have been £3,437 10s., shed and machinery included.

† Imported Oregon pine; as sticks of sufficient size and length (some running up to 12 inches by 12 inches by 41 feet) could not be obtained in the district.

TABLE II.

Showing the Cost of Free-milling and Grinding-milling Treatment in various Localities.

	Europe.			Asia.		South America,	Australia.						New Zealand.	South Africa.	
	Wales.		Italy.	Wynaad.	Mysore.	Venezuela.	Burdekin	Charters Towers.			Rishton.	Victoria.	The Thames.	Johannesberg.	
Name of mill	40-Stamp Mill. New Morgan	..	Pestarena. Cost per ton of picking and crushing in stone breaker and rolls, 2s. 8¾d. Do. of amalgamation, including mercury, wear and tear, etc., 6s. 2d.	20 Stamp. Indian Phœnix.	90 Stamp Mill.	60 Stamp. El Callao	60 Stamp. Day Dawn Block.	*o* 40 Stp. Day Dawn	50 Stp. P.C.	25 Stamp. New Queen.	20 Stamp. Disraeli.	60 Stamp Mill. S. Clunes United.	33 Stamp Mill. Saxon.	20 Stamp. May Consolidated.	100 Stmp. The Jumpers.
Tons crushed	1891. 960 (= 21,760 12 mos.)	1891. 1,700 (= 19,550 12 mos.)		1884. 250 (= 12,574 12 mos.)	1892. 38,727	1891. 58,949	1890-91. 20,078	1889. 21,920	1890. 27,636	1889. 5,113 (= 10,226 12 mos.)	1887. 890 (= 10,680 12 mos.)	? 28,820	? 63	1889-90. 14,992	1889-90. *w* 24,795
Time crushing lasted ..	320 hours	627½ hrs.		6 days.	12 mos.	12 mos.	12 mos.	12 mos.	12 mos.	6 months	1 month	12 mos.	24 hours.	12 mos.	6 mos.
	s. d.	s. d.		s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Labour per ton crushed, cost	0 8	0 10½		0 11¼	..	..	4 3½	6 5	5 5¾	5 10	4 9½	0 10½	2 10½		
Material..	0 2	0 6¼		1 0¼	..	..	0 11	2 0½	1 6¾	1 5	1 0			13 0½	10 1
Fuel	..			Nil.	..	..	1 7½*m*	2 4*p*	2 3*p*	2 2½*p*	1 3¾*m*	1 4½	?		
Repairs	?	?		0 8½	..	..	1 1½	0 6¾	0 1	0 4½	0 1½		1 2½		
Transport	0 6½	0 7		0 5	..	..	2 2*n*	0 6½*q*	0 3½*r*	2 4*s*	0 6*t*	0 8¶	?	2 6¾	0 10½
Water	Nil.	Nil.		Nil.	..	..	Nil.	Nil.	Nil.	Nil.	1 5¼*u*	Nil.	Nil.	Nil.	Nil.
Total cost per ton, using as motive power — Water ..	*a*1 4½	..	*b*8 10¾	*c*3 0¾	..	..	..	..	..	..	..	..	..	..	..
— Steam ..	..	..	..	..	†14 6	*d*5 0	*f*10 1½	*g*11 10¾	*h*9 7¾	*i*12 2	*j*9 2	2 11	4 1	*v*15 7½	*x*10 11¼
— Water and steam ..	..	*a*1 11½	..	..	..	..	..	..	..	..	..	..	..	..	..

TABLE II.– *Continued.*

	North America.						
	Alaska.	Dakota.				Colorado.	California.
Name of mill	240 Stp. Alaska-Treadwell.	80 Stamp Mill. Homestake ..		120 Stamp Mill. Golden Star.		75 Stamp Mill. Hidden Treasure.	40 Stamp Mill. Empire.
Tons crushed	1890-91. 220,686	1887-88. 96,790	1880 153,372	1880. 121,910	1887-88. 146,565	1891. 30,720	? 21,000
Time crushing lasted ..	12 mos.	12 mos.	12 mos.	12 mos.	12 mos.	12 mos.	12 mos.
	s. d.	s. d	s. d.	s. d.	s. d.	s. d.	s. d.
Labour per ton crushed, cost	0 9¾[k]	1 0½	2 2¾	1 4½	0 10¾	1 7	0 10¼
Material	0 6½[i]	*0 2¼	0 8½	0 3½	0 2¼		0 5¾
Fuel	0 3⅝	1 1¾	1 2¾	1 0⅝	1 1¾		
Repairs	0 1½	0 4½	0 8	0 1⅝	0 6½	1 8	0 4
Transport	?	?	0 1½	?	?	?	?
Water	Nil.	0 8½	0 5½	0 5½	0 8½	?	Variable.
Total cost per ton, using as motive power: Water ..	[e]1 9	..	..	..	..	..	1 8‖
Steam ..	..	[y]3 5½	[z]5 4¾	[z]3 2¾	[y]3 5⅝	..	..
Water and steam ..	..	..	..	..	..	3 3¼	..

a Manager's Reports, June to November, 1891.

b Estimate of "the agents."

c Report by the writer, August, 1884, published by the company, January, 1885. With a 20-stamp mill, possessing good fall, arranged with rock-breakers, stamps (with inside and outside "coppers"), and vanners, these costs could probably be reduced to 1s. 10d. per ton in India under like conditions.

d Report of Mr. George E. Webber, Jun., Superintendent, 1891. (6·29 fr. = 5s. per ton.) For the year 1891, 1,589 cords of wood were used, equivalent to 800 tons of coal of fair quality, costing £4 7s. per ton. In addition to crushing 58,949 tons of quartz, the engine did other work (pumping water and driving dynamo for hoisting-works, etc.), so only about three-quarters of the power employed was used for milling. Hence fuel used per ton of ore was equivalent to about 22 lbs. of good coal. The engine used at El Callao is a compound condensing tandem, supplied with steam by locomotive boilers with combustion chambers; steam pressure, 140 to 150 lbs. Mr. Hamilton Smith, Jun., (Notes on Gold Quartz Milling at El Callao, March, 1892) remarks, considering the high cost of labour supplies and fuel at El Callao:–"This is an exceedingly low rate. The above cost of 6·29 fr. per ton includes 0·60 fr. per share of general expenses. Such a charge is not generally made to milling accounts, so on the usual basis, the cost per ton for milling was 5·69 fr. or 4s. 6d."

e Company's Annual Statement, 1891.

f Company's Report, July 14th, 1891.

g Company's Report, 1889.

h Company's Report, 1890.

i Manager's Report, December 31st, 1889.

j Estimated by the writer. Mr. C. P. Purinton, who reported on the Disraeli in 1887, stated in his Report published by the Company, page 9, that "the cost of milling depends in a great measure on the quantity milled," adding:–"If the mine supplied ore enough in sufficient quantity to keep the mill constantly employed, the ore could be milled for not to exceed 5s. per ton, whereas the cost now is fully 10s." If general expenses and management (which for the sake of uniformity with the other mills is not included in the author's figures) be apportioned and added to his estimate, it tallies almost exactly with Mr. Purinton's. An extra charge per ton milled ought to be added to all estimates for the amortization of the capital, calculating it at from 10 to 15 per cent. of the gross cost of the plant, according to the probable life of the works. It is not unusual to write off 5 to 10 per cent. on machinery and 2½ to 5 per cent. on buildings; but this proportion depends on circumstances, where (as in some cases) the materials of the building when "sold off" would command a better price comparatively speaking than the machinery.

TABLE II.—*Continued.*

ALASKA-TREADWELL.

k Subdivision of Labour—	Cost per Ton. Dol.
Foremen	0·0215
Amalgamators	0·0258
Feeders	0·0402
Oilers	0·0098
Concentrators	0·0333
Rock-breakers	0·0168
Do. (whites)	0·0343
Ditchmen	0·0090
Do. repairs	0·0033
Total	0·1940

l Subdivision of Material—	Cost per Ton Dol.
Shoes and dies	0·0608
Concentrator fittings	0·0078
Screens	0·0034
Rock-breaker supplies	0·0059
Feeder do.	0·0032
Miscellaneous	0·0032
Guide-blocks	0·0009
Oils and lubricants	0·0013
Lumber	0·0015
Rope and hose	0·0029
Water-wheel supplies	0·0019
Mortar and aprons	0·0082
Mercury	0·0088
Cam-shafts	0·0022
Battery linings	0·0029
Electric light	0·0062
Total	0·1211

m The Disraeli and, the writer believes, the Day Dawn Block use tubular boilers.

n Transport by rail (12 miles).

o In 1889, 10 stamps, 12 Berdans, and 2 concentrators were added to the plant (specified in Table I.) and came into operation the following year.

p The Day Dawn P.C. and New Queen use Cornish boilers, owing to the corroding action of the Charters Towers water. Fuel is also somewhat cheaper at Rishton and the Burdekin than in the Towers.

q Transport by rail (1½ miles). *r* Ditto (1¼ miles). *s* Transport by cart (¾ to 6 miles).

t Transport by horse-tramway (½ mile).

u Labour, 10¾d.; fuel, 6½d. Pumping 150 gallons 2,500 feet, with a vertical lift of 108 feet.

v Report of the Company for year ending May 31st, 1890.

w Average duty of stamps, 2 tons 14 cwts. 3 qrs. per 24 hours.

x Report of the Directors for the half-year ending January 31st, 1890. The cost of milling during this period varied, it may be remarked, from month to month (from as low as 9s. 2d. per ton crushing 4,976 tons; to 22s. 8¾d. crushing only 1,245 tons).

y "Gold Milling in the Black Hills," by H. O. Hofman.—*Trans. Am. Inst. Min. Eng.*, vol. xvii., p. 498.

z Tenth Census of the United States, page 280.

* Includes supplies, candles, oil, mercury, lumber, and timber.

‡ Water power used for four months, steam for four months, and both water and steam for remainder of year.

‖ This figure is an average, the cost varying from 1s. 5½d. to 1s. 10½d. When steam is used 5d. extra must be added to the total given.

¶ Tramming the stone one-third mile and breaking it on contract.

† Of this sum 5s. to 6s. 6d. is probably chargeable to treatment of tailings by grinding.

NOTE.—To institute a fair comparison between the total cost at the different mills recorded in the table, the cost of transport must, of course, be deducted from the total cost, making allowance as well for difference in the relative quantity crushed in each case, etc.

The cost of treatment in different localities, using the same milling process, is quite as variable as the cost of plant.

The author does not think he is overstating the fact in saying that at most of the older Charters Towers batteries (with 15 to 20 heads) the cost of milling runs from 14s. to 18s. per ton and more, including only such items as are given in Table II.

At Plant's mill, according to the report of the company (*Northern Miner*, September 19th, 1889), the profit for the year ending December 31st, 1888, was about £3,000, and if the stone milled be taken at 13,500 tons and the charge for crushing, including grinding, is assumed to have

TABLE III.

Showing Ruling Rates of Wages in Different Localities and Staff of Various Mills.

Occupation.	20 Stamp Mill, India.			80 Stamp Mill, Dakota.*			120 Stamp Mill, Dakota.†			40 Stamp Mill, Wales.‡	
	No. of Men.	Length of Shift.	Wages per Shift.	No. of Men.	Length of Shift.	Wages per Shift.	No. of Men.	Length of Shift.	Wages per Shift.	Length of Shift.	Wages per Shift.
		Hrs.	s. d.		Hrs.	s. d.		Hrs.	s. d.	Hrs.	s. d.
Foremen	1	...	...	¾	...	27 1	¾	...	27 1	...	...
Amalgamators ...	2	12	3 4	1	10	16 8	1	10	16 8	12	6 6
Assistant do. ...	1	12	1 5½	4	12	14 7	4	12	14 7	12	5 6
Rock-breakermen	...	...	...	5	10	12 6	6	10	12 6	12	4 0
Feeders & stone-breakers ...	14	12	0 8¼	2	12	12 6	4	12	12 6	12	4 0
Oilers	1	12	0 8¼	2	12	12 6	2	12	12 6	...	...
Machinists ...	..	...	3 4	1	10	17 8½	1	10	17 8½	...	...
Pipe-fitters ...	...	...	...	¼	10	14 7	¼	10	14 7	12	4 6
Engine-drivers ...	...	...	3 5¾	2	12	14 7	2	12	14 7	...	...
Firemen ...	...	...	...	2	12	12 6	2	12	12 6	...	...
Blacksmiths ...	1	12	1 8	...	...	...	...	...	...	...	...
Strikers	1	12	0 7¾	...	...	...	...	...	...	...	...
Carpenters ...	1	12	1 8	...	...	...	...	...	...	...	...
Labourers ...	2	12	0 8¼	...	...	...	...	...	...	8	3 6
Watchmen, etc....	4	12	0 8¼	½	12	12 6	½	12	12 6	...	...
Panmen & oilers	...	...	...	...	...	...	...	...	...	...	...
Vanner-attendants	...	...	...	...	...	...	...	...	...	...	...
Total number	28	...	...	20½	...	...	23½	...	...	...	...

* Homestake. † Golden Star. ‡ Morgan G.M.C.

been somewhere about the usual price of 18s. to 22s. per ton,* then taking it at 19s. per ton, it leaves a balance of £9,825 for milling expenses during the year, which, divided by the gross tonnage crushed, would represent a milling cost of about 14s. 6¾d. per ton. This is a case of special interest, because wheelers are used entirely for grinding and amalgamating, to the exclusion of berdans, in which respect this mill differs from most of the others in the district. An examination of Table I. shows, however, that the cost of milling in the same locality varies greatly, depending upon:—

1. The general design and internal arrangements of the mill-building, for economizing and facilitating labour, and simplifying the plant, depending to a great extent on the selection of a suitable site and its proper utilization.
2. The general nature of the process in regard to the saving or loss of gold and mineral, which the disposition and character of the machinery effects.

* Depending on the amount of pyrites in the stone, and the time taken to grind a given tonnage (varying with the capacity of the pan).

TABLE III.—*Continued.*

Occupation.	20 Stamp Mill, Disraeli, Rishton. No. of Men.	Length of Shift.	Wages per Shift.	Charters Towers. A 10 Stamp-battery	A 15 Stamp-battery	A 20 Stamp Mill.	A 25 Stamp Mill.	Length of Shift.	Wages per Shift.
				No. of Men.	No. of Men.	No. of Men.	No. of Men.	Hrs.	s. d.
Foremen	...	...		...	..	...	...	...	...
Amalgamators ...	1	12		2	2	2	2	12	16 8
Assistant do. ...	2	8		...	...	...	...	8	13 4
Rock-breakermen	1	8		...	...	...	...	8	10 0
Feeders & stone-breakers ...	1	8	Rates much the same as at Charters Towers.	3	4	5	6	8	10 0
Oilers	...	...		...	...	...	...	...	...
Machinists ...	½	...		1	1	1	1	12	16 8 / 18 4
Pipe-fitters ...	...	...		...	...	...	...	...	...
Engine-drivers ...	3	8		3	3	3	3	8 / 12	11 8 / 13 4
Firemen ...	...	...		...	...	...	...	...	...
Blacksmiths ...	...	...		...	...	...	...	8	13 4 / 16 8
Strikers	...	...		...	...	...	...	8	10 0 / 11 8
Carpenters ...	...	...		...	...	...	...	8	15 0
Labourers ...	...	...		...	...	...	...	8	10 0
Watchmen, etc....	...	...		...	...	...	...	8 / 12	10 0 / 11 8
Panmen & oilers	2	...		1 to 2	2	2	3	8	10 0 / 11 8
Tailingsmen and Vanner attend'ts.	1	...		*1	*1	*2	*2	12	11 8
Total number	11½	...	...	11 to 12	13	15	17	...	...

* Tailingsmen.

3. The gross tonnage that is handled by the mill in a given time (sometimes affected by climate).
4. The efficiency of the labour employed, and its cost.
5. The quality and the price of supplies, fuel, etc., used.
6. The power employed, and its method of application.
7. The situation of the works as regards water-supply, transport of ore from the mine to the mill, and disposal of tailings.
8. The efficiency of the general management.

All these points have to be studied from the standpoint of relative utility and comparative cost.

As regards the author's first proposition, effect of general design, nothing could illustrate what is meant better, than the saving of labour and material (as shown by Table I.) effected in mills, laid out like the Day Dawn block and Disraeli, as compared with batteries of the New Queen and Day Dawn P.C. type.

TABLE III.—*Continued.*

Occupation.	60 Stamp Mill, Dakota, California.			40 Stamp Mill, California Empire.			75 Stamp Mill, Colorado, Hidden Treasure.			35 Stamp Mill, New Zealand, Saxon.		
	No. of Men.	Length of Shift.	Wages per Shift.	No. of Men.	Length of Shift.	Wages per Shift.	No. of Men.	Length of Shift.	Wages per Shift.	No. of Men.	Length of Shift.	Wages per Shift.
		Hrs.	s. d.		Hrs.	s. d.		Hrs.	s. d.		Hrs.	s. d.
Foremen... ...	1	...	27 1	...	...	...	...	...	...	...	...	...
Amalgamators ...	2	12	15 7½	2	12	12 6	1	12	24 3½	3	8	8 0
Assistant do. ...	...	...	...	...	...	...	1	12	13 10½	...	...	...
Rock-breakermen	1	10	12 6	1	12	10 5	...	...	...	...	...	...
Feeders & stone-breakers ...	2	12	13 6½	...	...	...	6	12	12 6	3* 3†	8 8	6 8 5 0
Oilers	...	...	...	...	...	...	...	...	...	...	...	...
Machinists ...	1	12	18 9	...	...	...	...	...	...	...	...	...
Pipe-fitters ...	...	...	...	...	...	...	...	...	...	...	...	...
Engine-drivers ...	2	12	14 7	...	...	...	...	...	...	...	...	...
Firemen... ...	2	12	13 6½	...	...	...	...	...	...	...	...	...
Blacksmiths ...	...	...	...	...	...	...	...	...	...	...	...	...
Strikers	...	...	...	...	...	...	...	...	...	...	...	...
Carpenters ...	...	...	...	...	...	...	...	...	...	...	...	...
Labourers ...	1	10	10 5	2	12	10 5	...	...	...	...	...	...
Watchmen, etc....	...	...	...	...	...	...	...	...	...	...	...	...
Panmen & oilers	...	...	...	...	...	...	...	...	...	...	...	...
Tailingsmen and vanner-attendants	...	...	...	1	12	12 6	2	12	12 6	3	8	3 4
Total Number	12	...	...	6	...	...	10	...	...	12	...	...

* Men. † Boys.

Wages in Wales run from 21s. to 39s. per week. The staff is composed of 7 men by day and 3 by night at the Morgan mill.

Wages in Italy run from 9½d. to 3s. 8d. per day at Pestarena. Girls earn 9½d. to 11d. per day; mill-men, 2s. per day; labourers, 1s. 6½d. to 1s. 9d. per day; Smiths, 2s. 5½d. to 3s. 8d. per day.

Wages in South Africa are as follows:—Amalgamators (European), £20; assistant amalgamators, £15; rock-breakermen, £17 10s.; machinists, £30; engine-drivers, £26; blacksmiths, £30; carpenters, £22 10s.; and labourers, £13 per month. Natives earn £3 per month. The Jumpers mill employs a staff of 13 Europeans and 65 Kaffirs, with 4 European vanner-attendants and 5 Kaffirs in the vanner-house.

As both the Day Dawn batteries are first-rate mills of their class, and are in charge of first-class Queensland mill-men, and both the New Queen and Disraeli were under the writer's management, when the figures given in Table II. were compiled, he has no hesitation in taking these four plants for comparison. In regard to the New Queen, it will be noticed that the charge for labour, material, and repairs amounted to 7s. 7½d. per ton in 1889, as compared with 5s. 11d. at the Disraeli in 1887, a difference in favour of the latter of 1s. 8½d. per ton, notwithstanding the extra charges on supplies, etc., involved in transporting goods of every sort, an additional 22 miles to Rishton. What lends these two cases special value is the fact that, for all practical purposes, the 3rd, 4th, 6th, and 8th of the above considerations may be considered practically the same in both. The 1st, 2nd, 5th, and 7th are therefore evidently what really affect the point under consideration.

The nature of the plant affecting as it does the cost of treatment, must be always recognised in considering the cost of a mill. Now, if we assume, for instance, an equal tonnage crushed in the New Queen and Disraeli batteries, amounting to 10,000 to 12,000 tons per annum (running the same number of stamps) it is evident that there is a gross saving of between at least (1s. 8½d. × 10,000 =) £854 3s. 4d. to (1s. 8½d. × 12,000 =) £1,025 annually in favour of the Rishton works. Against this, strictly speaking, however, one must place the interest (reckoned say at 4 per cent.) on the extra capital outlay expended on the latter mill which, if we include accessory plant (such as reservoir pumping-station and race) is assumed to amount as before stated to about £3,000.

It will be noted that if one were to take the Burdekin or Excelsior batteries for comparison, from the costs given in Table I., the difference in the former case on 20 stamps erected would be £2,620 against the Disraeli. This, however, is easily explained by the difference in freight rates and the proportionately lower cost of constructing a large mill as compared with a small one; and as a great deal of the machinery was got from Maryboro' it had not to pay duty. In the case of the Excelsior mill it would be (20 × £250 =) £5,000 in favour of the Rishton mill.

It is indeed more than probable that, given the same mill-site, if the Disraeli battery had been erected at Charters Towers, it would have cost but little more than the New Queen per stamp-head, but taking the assumed capital expenditure in the two cases, and deducting interest as before remarked on £3,000 at 4 per cent., or £120 on the most unfavourable supposition; we might fairly attribute a net economy per annum of (£854 3s. 4d. − £120 =) £734 to (£1,025 − £120 =) £905 to be credited simply to the general design of the building and character and disposition of the machinery, which would repay the assumed extra capital cost with interest in between 3 and 4 years. What applies in this case evidently applies equally to any other similar 20 stamp mill in Queensland, entirely apart from the extra saving of gold a properly arranged mill is likely to effect; a matter which, though intimately connected with the question, comes under the author's second heading.

The saving that may be effected by arrangement of plant would, however, be far more striking if one had for comparison a 40 stamp mill, built like the Disraeli with a 40 stamp mill of the ordinary Charters Towers type, since the former could be run with 4 or 5 extra

men making say 16 all told, whilst the latter would require with the most careful management at least 24; while for an 80 stamp mill the numbers would stand relatively about as 26 to 44.

Reckoning mill wages on the average at 10s. 7d. per day (shift) and the working year at 303 days, this represents a saving on wages alone, running a 40 head battery, of £4 4s. 8d. per diem or £1,282 14s. per annum, or on an 80 stamp mill £2,886 1s. 6d. per annum, *plus* the extra saving on supplies, repairs, etc., which reckoned at only 8d. per ton would amount to a considerable sum, say £666 to £1,333 additional.*

The first cost of machinery is often only a small part of the total cost of erection, and it is therefore of the first importance that the best design and execution should be insisted on.†

Again, Messrs. McDermott and Duffield cite the case of two gold mills in Venezuela, running side by side, and owned by the same company, which well illustrates this. Both are 66 stamp mills operated on the same ore. The one poorly designed and built, the other embodying the results of practical mill-men's experience. The one mill can be made to average 93 tons crushed daily. The other averages over 143 tons. The first costs in working expenses, 18s. 9d. per ton of ore, the latter only 6s. 8d. These mills are ordinary gold mills, and it will appear incredible to those who have not run such machinery that such differences can exist, believing that a stamp mill is merely a medium for crushing, and that economy always consists in purchasing it in the cheapest market and erecting it anyhow.

The author's second proposition, viz., the saving or loss of gold, the details of the arrangement of a mill effects is one that is exceedingly complex, as there is an infinite choice of machinery and method of

* As bearing on this question the report of the Superintendent of the El Callao, 1891, may be quoted:—"Notwithstanding the increased amount of work the mill has had to perform and its growing age, few renewals and repairs have been required, and at the close of the year all its parts remain in good running condition."

† Mr. Hamilton Smith, Jun., says: "The old El Callao mill for the year 1882 crushed 22,405 tons of quartz at a cost of 78·30 francs per ton. A comparison of these results with the results (see Table II.) obtained by the new mill is very instructive to mining men; as there could be no better proof of the advantages of first class mining machinery coupled with judicous management. Had it not been for the construction of this new mill, El Callao mine would have suspended operations years ago." The cost for the year ending December 31st, 1892, was 6·22 francs per ton, whilst the average assay of the tailings was 3½ dwts. per ton.

grouping it, which more or less affect the question, depending on the nature of the ore; various illustrations of this will, however, be given later on.

It is a matter which must be confided to the technical knowledge and experience of the engineer who designs the plant presumably with certain specified objects in view, a number of which have been incidentally noticed. The losses in gold-milling are, like local costs, extremely variable.

In Gilpin County, Colorado, for example, 113,427 tons were milled during the census year ending May 31st, 1880, out of which :—

Per Cent.	
65	of the gold was saved by direct amalgamation.
4	" " pan treatment
7·05	" " re-concentration of tailings.
Total, 76·05	The ore running £2 1s. 3¼d. in gold and 1s. 3d. in silver.

The above agrees with the writer's experience in India, where he found 76·2 per cent. was saved by direct amalgamation and pan treatment.

The latest recorded results of one of the best mills of Gilpin County, which is said to be fairly representative of present Colorado practice, shows that treating an ore containing 7·46 ozs. of gold and 32·86 ozs. of silver, it is possible to extract by milling 93·8 per cent. of the gold and 74 per cent. of the silver (including the value in the concentrates) out of which 70·4 per cent. of the gold and 42·6 per cent. of the silver was extracted by direct amalgamation. This, the writer thinks, shows, that whilst the saving by direct amalgamation in Colorado remains much the same as it was, a steady improvement has taken place in the manipulation of the pyrites.

Treating 25 dwts. ore at El Callao the loss is said to be 3½ dwts.; in 1891 it was 2¾ dwts. In Dakota, the Homestake and Golden Star mills claim to save 85 per cent. of the free gold, ½ to ¾ dwt. being unrecovered in the tailings. The tailings of the Alaska Gold-mining Company run ½ to 1 dwt.

Mr. G. T. Deetken, some years ago, made some elaborate experiments at one of the best Californian gold mills of the day, and found that 27 per cent.* was lost in the tailings giving an extraction of 73 per cent. At the present time, with improved methods of treatment, the extraction

* This, again, about corresponds, the author believes, with the average loss (gross) in the Charters Towers mill tailings, crushing and treating 25 dwts. ore; it may be assumed that in concentrating and grinding the pyrites, the loss runs from 5 to 7 dwts.

in California probably approaches nearer 80 to 85 per cent., and one instance might be cited where it was as high as 82 to 94 per cent., the concentrates being treated by chlorination.

As most gold ores contain some gold combined with pyrites, in all probability, the average extraction of most mills treating stone of this kind often falls short of 75 per cent., and is occasionally as low as 45 per cent. if the stone contains much pyrites, which is dealt with in a crude manner.

In Victoria, treating 5¼ dwts. to 5¾ dwts. ore, the average extraction at the present day in the best mills is about 84 per cent., and has run as high as 87·6 per cent., which is the best record grinding milling can show under the most favourable circumstances with an ore exceptionally free. The milling practice of the district has steadily improved since 1861, when there was actually a loss of nearly 50 per cent. of the gold in the stone.

Though miners, as a class, possess just as much honesty and hard common-sense as people who follow many other callings, when it comes to consideration of these mill losses (although they can only be remedied by knowing exactly where the loss occurs and what it amounts to) the behaviour of a certain section of mining people and mill-men when confronted with facts of this sort reminds one forcibly of the behaviour of the ostrich confronted with death. The bird, it is said, sticks his head into the desert sands, and affects to disbelieve in the possibility of loss of life. The unpractical individual who generally loves to self-style himself the practical man* (who don't believe in assays, underground-surveys, and that kind of thing!) buries his eyes in the mill-sands, declares, believing it or not, that there is no loss of gold, and the facts, whether, as in some cases, from honest conviction, in others from dishonest expediency, become falsified.

It is curious that shareholders in mines seem actually to prefer to be deceived in this respect, and the mill-man who tells them that there is a loss in their tailings is lucky if he escapes being abused as well as thought a fool, simply because his neighbours choose to declare that they are losing nothing!

In this connexion, automatic samplers may be used with advantage to sample the crushed ore, pulp, and tailings regularly.

In August, 1884, the author put through a test crushing (in India) of

* A very different individual to the genuine miner or mill-man, of whom the late Mr. George Langtry, of Comstock fame, might be taken as a real type. See "Amalgamation on the Comstock Lode, Nevada," by Mr. A. D. Hodges, *Trans. Am. Inst. Min. Eng.*, vol. xix., page 216.

280 tons of stone, the particulars of which (given below) may be of some interest. It may serve as an illustration of the kind of information which ought to be obtainable of the working of every gold mill, and shows how, if the ore is regularly assayed (as it ought to be constantly), the results can be checked.

Number of stamps, 20; weight of stamps, 850 lbs.; lift, 9 inches; speed, 58 drops per minute.

Duty of battery, 41·3 tons per diem, or 2 tons 145 lbs. per stamp.

Order of drop, 3, 1, and 5 together, and 2 and 4 together.

Water supplied to each battery of 5 stamps, 3·52 cubic feet, or 22 gallons per minute.

Water supplied to other parts of the mill, 16 gallons per minute.

Ore per cubic foot of water discharged from the battery, $\frac{1}{38 \cdot 13}$ cubic feet.

Mesh of screens, 196 holes per square inch (about $\frac{1}{37}$ inch).

Wear of shoes, $1\frac{1}{28}$ lbs. per ton of ore crushed.

Wear of dies, about half that of the shoes.

Amount of pyrites in the ore, $2\frac{1}{2}$ per cent.

Degree of concentration, 50 per cent.

Concentrates obtained from percussion-tables, 14 tons.

Yield of milled gold, 2 dwts. 10·7 grains.

Bullion fineness, 911·5

Tons of ore crushed, 280.

Time crushing lasted, 162 hours 35 minutes.

Mercury required to charge entire mill, 1,458 lbs.

Loss of mercury (owing to an accident at one of the mills this cannot be stated exactly).

	By Assay.	By Estimate.	Actually Obtained or Accounted for.
	Ozs. dwts. grs.	Ozs. dwts. grs.	Ozs. dwts. grs.
280 tons of ore, assaying 3 dwts. 5 grs. per ton contain	44 18 8	...	...
Gold obtained from stamp-boxes	...	...	2 12 0
Gold in the ore leaving the battery (deducting gold obtained from boxes)	...	42 6 8	...
Gold obtained from copper-plates	...	...	18 10 0
Gold in the ore after passing the plates (deducting gold obtained from plates and boxes)	...	23 16 8	...
Gold obtained from riffles	...	...	4 0 0
Gold in the ore after passing the riffles ...	*a*18 14 12	19 16 8	...
Gold obtained from the wheeler-pans ...	...	...	6 10 0*b*
Gold in the concentrated slimes leaving the wheeler-pans	12 5 0	12 14 12	...
Gold obtained from the Hungarian mills ...	...	...	2 13 0*b*
Gold in $9\frac{1}{2}$ tons of settlings, collected in catch-pits	7 8 1	...	7 8 1*b*
Gold in the tailings of the percussion-tables	1 12 0	1 11 20	1 11 20*b*
Gold in the tailings of the settling-tanks, and unaccounted for	...	1 13 11	1 13 11*b*
			44 18 8

The sum of the results marked *b* (19 ozs. 16 dwts. 8 grains) should equal the assay marked *a* (18 ozs. 14 dwts. 12 grains) to be theoretically absolutely accurate.

No efficient check can be kept on the work going on at a mine or mill without a proper record of the working of each department being kept by its immediate heads, and a subdivision of accounts, which shows the cost per ton, under different general heads, in detail from month to month.

The author's third proposition (the influence on cost of the gross-tonnage handled in a mill in a given time) is instanced by the results of milling at the Day Dawn P.C. mill in 1890 as compared with 1889, the effect of milling 1,140 tons extra in the latter year being to reduce the expense on each item of cost (Table II.).

Referring to the capital charges in 1890, the directors in their report make the following remarks:—"The capital expenditure in question has been fully justified, for it has already greatly reduced the working charges, as will be seen from the following table:—

Year.	No. of Tons Treated, excluding Mundic Stone.*	Total Cost of Reduction and Extraction of Gold.†	Cost per Ton of Ore Treated.‡
		£ s. d.	£ s. d.
1889	26,551	45,896 12 10	1 14 7
1890	28,879	42,924 16 7	1 9 9
	+ 2,328	− 2,971 16 3	− 0 4 10

showing that although 2,328 more tons were treated in 1890 than in 1889 the cost was £2,971 16s. 3d. less." This statement should be obviously reversed; the capital expended having increased the output in 1890 being the cause of the reduced cost.

Take once more, for example, the New Queen. The author has shown in Table II. that the average cost of treatment in 1889 was 12s. 2d. per ton, but as was remarked in the report published from which these figures were taken—from September to November (of the year in

* Including ore crushed at outside mills (the amount crushed at the company's own mill being given in Table II.).

† Including mine expenditure, mill expenditure, expenditure on Rose of England lease, crushing ore at outside mills, and bullion-remittance expenses account.

‡ The cost, including general expenses at Charters Towers, appears to have been £1 16s. 1¼d. in 1889 and £1 10s. 9¾d. in 1890.

question) the actual cost ranged from 9s. to 10s. 4d. per ton, according to the quantity of stone crushed, which varied from 1,162 tons to 943 tons per month.

The effect of the quantity milled on the cost of milling is again evident if we compare the cost of milling at the Homestake and Golden Star mines in 1880 (Table II.), and the cost of milling in the new 60 stamp mill* of the El Callao Company, during several different years, tabulated below ;—

Year.	Tons Crushed.	Cost per Ton. Francs.
1888	15,692	18·40
1889	43,629	12·60
1890	53,977	7·82
1891	58,949	6·29

The reason for this reduction is evident: with an enlarged scale of treatment, while the standing charges for management, skilled labour, etc., remain much the same, the amount of even the extra manual labour required is not by any means always increased in direct proportion to the additional tonnage crushed. It is to be recollected, however, that in crushing an extra quantity of stone its general average yield is likely to drop, as it often pays to crush stone in a large mill, which, with a smaller plant, would have to be discarded.

The yield of the Jumpers Company, for instance, crushing for six months with 30 stamps, fell from 18½ dwts., to between 10¾ and 11¾ dwts., with 70 stamps; and adding 30 stamps to the Robinson 10 stamp mill, the average grade of the ore fell 50 per cent.†

The Charters Towers gold-field, again up to 1889, is reputed to have produced 1,915,051 ozs. of gold representing a yield of 1 oz. 10 dwts. 9 grains per ton; in 1890, 121,406 tons 8 cwts. 2 qrs. of quartz were crushed for an average yield of 1 oz. 6 dwts. 19 grains; and 174,000 tons in 1891, which only averaged 1 oz. 5 dwts. 9 grains.

Allowance must consequently be made for this decreased yield per ton in estimating the probable profits of a large plant when calculations are made, based upon the yield of an existing small mill.

Another point, however, in favour of large mills is that labour can be more easily specialized, which tends to reduce cost by promoting increased manual dexterity in individual operations, whilst by running reduction works up to their full capacity (a thing to be always aimed at) the fractional excess of unproductive labour, or, in other words, the time

* Supplied in 1885 by Messrs. Fraser and Chalmers.

† Messrs. McDermott and Duffield, page 5.

thrown away that has to be paid for, to perform duties which do not occupy one or more men a full shift, is reduced to a minimum.

The author's fourth proposition (the influence of the efficiency of the labour employed on the cost of milling) has a most important bearing on the question. It has been admirably dealt with by Mr. W. M. Howe in "Notes on the Bessemer Process."* Though speaking of the manufacture of steel, his remarks, which are quoted with some slight adaptations, apply to all reduction works: "A skilled manager, amalgamators and engine-drivers you must have, be the output large or small, whether the works run continuously or but a certain part of the time. The difference is that in the case of works with a small output, much of the time of these men, which you must pay for in full whether you use it or not, is either wasted or dévoted to work, which in the case of a large output is performed by less intelligent, less skilled, less costly men; double your output and you scarcely need more of these highly skilled men. Most of the additional men are less skilled, many indeed are but assistants of the skilled nucleus which is necessary, and nearly as large in the case of the small as in that of large outputs, and though the foreman or mechanic who is to direct others, must add executive ability to the qualifications he would otherwise need and hence commands higher pay, yet the extra expense thus caused should raise the average cost of the daily wages, much less than it is lowered by the employment of the larger number of relatively unskilled assistants, due to the greater output. There are many trivial and very simple duties which call for little intelligence. With a large output those of each kind recur so often that cheap men can be fully occupied with them. The expensive men in cases of small output, do these trivial, simple acts with their costly labour, which in cases of large output is restricted to the difficult tasks which require it and which fully occupy it. Or, if justified by the greater output on the unit of which their pay forms a relatively small charge, you employ additional skilled and costly men, they are not mere duplicates of those you had before, they bring a different skill and additional knowledge to your aid, permitting economies and devising improvements otherwise unattainable."

This question of skilled labour, it will be noticed, is intimately connected with the production of the mine and capacity of the reduction works.

A large company, with perhaps several hundred men in its employ, requires the highest skilled organization to make it pay interest on

* *Trans. Am. Inst. Min. Eng.*, vol. xix., page 1,120.

a large capital, but the direct opposite may be said of a mine in its infancy, working on a small scale, with a small production, which generally means a small net profit. A staff of highly skilled and consequently highly paid officials would obviously be its ruin. It is therefore, fortunate that it is only when a mine reaches a certain size and depth, with a corresponding output, that the services of a skilled staff become indispensable to commercial profit on a large scale. There is a miners' saying that tributers will make a living where a company will starve, and there is a great deal of truth in it, if only because tributers have no general expenses to bear.

In the mining and milling of gold and silver ores, speaking from the writer's own experience, the skilled Anglo-Saxon workman, whether he be British, American, or Colonial, distances all competitors. Each subdivision of the race numbers in its ranks hundreds of miners (using the expression as covering mill-work as well) second to none in the world, though not a cheap man certainly. The payment of a low rate of wage to the skilled workman is by no means the only, or indeed the most expedient means of lowering the cost of production, since the cost of a day's labour in any responsible occupation is in reality in inverse proportion to the intelligence as well as the sinew and endurance it represents, and in reducing the rate of the one you run great risk of lowering the standard of the other, so long as superior skill can command better wages elsewhere.

The writer's contention is that the cheapest skilled labour is not always, indeed is very rarely, the most economical, if only because the highly-paid man is the most contented, better fed, and better housed man, and the author proposes to show that it is quite possible to cheapen costs without lowering wages, providing a reduction in working expenses is not demanded suddenly, whether by strikes or market fluctuations. To illustrate this,* the Atlantic mine, in Michigan, which produced native copper from 1873 to 1877, scarcely made ends meet, and had to levy calls; since then, with the price of copper steadily declining, and also the yield of the ore, the cost of mining has been so greatly reduced that the company has made a profit every year. The workmen, who earned on an average from £10 8s. 4d. (50 dollars) to £12 5s. 10d. (59 dollars) a month in 1873, continue to earn almost as many dollars, and owing to the greatly reduced cost of living they are now very much better off and save really more money than they did twenty years ago.

* These particulars are taken from a leader on "The Free Coinage Question," in the *Engineering and Mining Journal* (New York), vol. lii., page 497.

The chief items of cost at the Atlantic mine for three years are shown in the following table:—

	1873.	1880.	1890.
Tons treated	51,048	169,825	278,300
Pounds of ingot produced	863,366	2,423,225	3,619,972
Percentage of yield	0·81	0·71	0·65
Average selling price, cents. per lb. ...	26·66	20·55	15·21
Cost of stoping per fathom	$22·28¼	$14·35	$4·21
„ driving per foot	19·09½	12·90	5·10
„ sinking shafts per foot	38·03	18·04	22·90
Cost per ton, mining and all surface expenses, taxes, etc.	5·12	2·14	1·04
Cost of transport, 3 miles from mine to mill, per ton	0·15	0·09½	0·03½
Cost of stamping and concentrating ..	1·05	$0·38^{18}$	$0·27^{78}$
Cost of freight, smelting, marketing, and New York office, cents. per lb.	$0·34^{9}$	0·33	$0·20^{37}$
Total expenditure per ton of rock treated	8·26½	2·47	1·67
Net profit per ton of rock treated	...	0·22	0·29¼
Loss do.	4·53	...	...

It would appear from this table, that since wages have practically remained unchanged, or are in fact higher (considering what they will purchase), the reduction in the cost of producing copper is due to improvements in mining, in stoping, in drifting, and through the use of rock-drills, high explosives, and other modern improvements, reductions in freight charges, in milling, and concentrating, in smelting and marketing, due to improved systems of doing the work.

All this shows that improved processes, greater facilities for the distribution of products, and greater skill and economy in the management of business have brought about the lower prices of recent years, and with them have added to the general prosperity.

If you look for the cause of these developments of the practical science of mining, it may be traced largely to technical education, the development of technical societies and technical literature. Mr. John Birkinbine, in his presidential address at the Montreal meeting of the American Institution of Mining Engineers,* states that there are to-day in the United States four engineening societies of a national character, with a membership as follows: —

	Founded.	Membership.
Society of Civil Engineers	1865 ...	1,650
Institution of Mining Engineers ...	1871 ...	2,400
Society of Mechanical Engineers ...	1880 ...	1,650
Institution of Electrical Engineers ...	1886 ...	650

* *Trans.*, vol. xxi., page 962.

A few facts selected from many which could be mentioned, illustrate the progress made during the existence of the American Institution of Mining Engineers from 1871 to 1893. The annual output of iron ore has increased from 3,000,000 to over 16,000,000 gross tons. One and two-thirds million gross tons of pig-iron was the output of the blast furnaces of the United States at the birth of the American Institution. Last year shows a total of over 9,000,000 gross tons, while, owing to improved construction and methods, a smaller number of furnaces yield the larger quantity of pig iron; three-quarters of the American product being produced with coke. The growth of the American steel industry is not less remarkable, and the enquiry might be carried further into the manufacture of rails, plate and bar-iron, and steel nails, cars, machinery, and great works fitted with superb appliances for fabricating them. The statement that a ton of pig-iron, of bar or plate-iron, or a keg of nails now sells at from 33 to 40 per cent. of what was received for it in 1871, whilst the price of steel rails is but 25 per cent. of what these commanded in 1871, is an eloquent commentary on the debt mining owes to the development of scientific principles by mining institutions. In 1871, the greatest depth which had been reached in any of the Lake Superior copper mines was 1,000 feet, and the price of copper stood at 30 cents and upwards, yet it was then impracticable to work those mines which did not produce mineral carrying 2 per cent. or more of copper. At the present time there are mines in the same district 4,000 feet deep, and with copper selling for 12 cents per pound, mineral yielding 0·6 per cent. is raised from a depth of 2,000 feet, crushed, jigged, and delivered at refining works, and sold at a moderate profit on the operation.

The hydraulic elevator and the deflector applied to hydraulic mining are inventions of great practical importance, which only date back, the one to 1870, and the other to 1876, and, under favourable conditions, gold-gravel has actually been hydraulicked for as low a sum as 3 cents per cubic yard. Figures will be found in this paper which illustrate the advances that have been made in reducing the costs of quartz mining, and improving the extraction of gold, etc., by chlorination and concentration.

Pan-amalgamation for silver-ores has been bettered and cheapened, and silver-lixiviation, direct matte-smelting, and the cyanide process are all modern processes born of scientific enquiry, which have made important advances and are likely to bear yet better fruit. Silver-lead smelting has been greatly developed, the so-called practical smelter having given place to the chemist and lead-metallurgist, cleaner and better work is now

done than formerly, lower-grade lead-ores are utilized, and lead-slags made in 1878 are now being re-worked.

Advances have been made in the utilization of electricity, the producfion of aluminium, and a host of other directions for which the world is indebted to the efforts of members of societies like those named in the United States, the various branches of the Federated Institution of Mining Engineers, which numbers over 2,000 members, the Iron and Steel Institute with 1,500 members, the Institution of Civil Engineers with 6,000 members, the Institution of Mechanical Engineers, of about the same size, and similar institutions in Germany, France, and other parts of the world working for a common object.

Any union for mutual advancement commands esteem, so long as the better element of membership is not hidden or overruled by selfish purposes controlling the administration of affairs to the disadvantage of its mutual progressive features. A past president of the Iron and Steel Institnte, alluding to the visit of that Society to the United States in 1890, expresses, the writer thinks, the mission and achievments of technical associations for the advancement of engineering, and of mining and metallurgical knowledge, in words which may be appropriately quoted:— "The expeditions, through which we meet eye to eye and voice to voice our friendly competitors, to discuss the interests and the scientific aspects of the industry which absorbs us, has been of great personal and national benefit. It is thus we learn how much has been accomplished by persistent and intelligent labour, how much remains to be achieved, and how, by the free exchange of ideas, and of productions, friendly understanding is promoted, and personal acquaintance is built up."

The author's fifth proposition (the influence of quality and price of supplies, etc., used upon the cost of milling) needs no demonstration, but in regard to the sixth and seventh (the power employed and the situation of the works), the Disraeli and New Queen mills will once more serve as illustrations, the former showing an economy both in cost of fuel and transport. (Table II.) This may be partly explained by the Disraeli boilers being of tubular pattern, and being run up to their full capacity, avoiding waste of surplus steam,* and as regards

* At the New Queen and other Charters Towers batteries, Cornish and Lancashire boilers are almost exclusively used, owing to the character of the feed-water which incrusts the tubes; and at the former mill (as is often the case) the engine-power is largely in excess of the immediate requirements, being intended to provide for any enlargement of the plant.

transport, the Rishton works enjoyed the advantage of a tramway between the mine and mill. Of course where water-power is available it offers a large saving over steam. Taking the total actual net difference in the cost of milling at the two mills, viz: 3s. per ton attributable to the natural advantages of location, and other causes that have been pointed out, if the one mill has actually cost let us suppose £3,000 more than the other to erect, it is certain that on a steady output of 40 tons per diem, it would have paid this sum back with interest in less than two years by effecting a saving of £1,480 to £1,780 per annum, or about £125 to £150 per month.

There is a good deal also to be said about the eighth factor in the case (the efficiency of the general management), as it is the master-key to the whole business.

If the workman is to demand and obtain high wages in the future it will only be by employing high-class technical and business skill in the management and conduct of operations, so as to take advantage of every practical scientific improvement which tends to cheapen the aggregate cost of production, whilst duly proportioning wages in all departments to relative efficiency and usefulness, whether in respect of mental attainments or manual dexterity. Unskilled labour can no more hope to compete with skilled workmen living in comfortable circumstances (though they be highly paid), in a field where skill is required, such as mining, than the skilled workman can expect to banish cheap labour from a field where nothing but slight manual effort and intelligence are needed.

We have seen that the difference between the cost of working in one mill as compared with another depends on its design, location, quantity and kind of ore put through it in a given time, the number and character of the external appliances for catching gold or other metal after it leaves the crushing machinery, the cost of fuel, labour, and supplies, the power available, and the organization and *personnel* of the staff, which directly depends on the general management. In regard to this last essential the gross cost of operations is nothing to gauge it by, the only certain proof of efficiency and economy is the ratio which the cost of handling and treating a given tonnage, bears to the percentage of gold or other metal saved when compared with other parallel cases.

Technical skill, combined with business management, in dealing with material and with men is absolutely necessary nowadays for the regulation of work, as the general efficiency of the staff as well as the expenditure on supplies, etc., depends upon it. Discrimination in employing the right man and the proper material in the right place, is the pivot upon

which management turns, though it amounts in the former case simply to a knowledge of the time when to put on an extra man at a profit and when to knock one off the pay-sheet, where to employ a mechanic and where to make shift with a labourer—a knowledge only to be gained by experience of men and materials.

Where you have to deal, as you must in any large mining undertaking, with the three different factors of brain, manual skill, and muscle, it is not less ridiculous for instance to place a man, who may be perhaps an adept at spalling stones, in charge of a mill at the salary of a first-class foreman, than it would be to put the latter to cob ore at the wage of a labourer.

Engineering knowledge and business capacity are co-essentials in selecting as well as in managing modern metallurgical processes and mining enterprises. The capitalist who fails to recognize this "knocks a nail from the inside into his own coffin." The miner who does the same, throws a stone at the only bird which can lay "the high-priced golden egg," where, as in some localities, the sum of his daily wage amounts perhaps to a half-guinea or more.

No one can doubt that the question of mutual and fair adjustment between the two co-important trade factors of capital and labour so as to enable both to exist in harmony, is fast becoming the burning problem of the hour, as it certainly will be of the next decade, or at any rate the next century, and it is certain that the prop upon which the very existence of the miner and the capitalist mutually depends is science practically applied. The miner who thinks otherwise is simply footing his stulls on treacherous ground, which will sooner or later break away with him, and entomb himself and his mates in the *débris*, whilst, as for the guinea-fowl who selects the board-room merely for a roosting place, he will equally promote his own extinction, becoming with the decay of all mining enterprise worth the name like "the dodo."

Messrs. McDermott and Duffield remark*:—"It is not possible to supply the lack of skill and experience by instructions and the owners of mills should take the only safe course in this part of the business by employing a good mill-man who has a record of successful work elsewhere. The owners of a mine or directors of a company may be impressed by the bearing and talk of an applicant for the position, but the frequent and lamentable failures resulting from this method of choosing a mill-man are proof of its inadequacy. Testimonials as to character and experience need just as much examination as the applicant

* *Gold Amalgamation*, page 13.

himself. Past successful record in modern mills is the only testimonial of real value. The salary to be paid a good man should be the last consideration. A cheap man is often a ruinous investment, where the final success of a mining investment rests on the successful treatment of the ore."

Another most important factor of success in running a mine in "loyalty." Loyalty to his immediate chief the miner or mill-hand owes to his shift-boss; the shift-boss to the mine-captain or mill-foreman the same as they owe it to the manager or superintendent, and he in his turn is bound to protect his employers' interests, as represented by his directors. As miners, in whatever walk of life we are placed, whether as employers or employed, we owe loyalty to our industry and to one another; both to those dependent on us and to those we are dependent on. Nothing is more fatal to the proper handling of large bodies of men, whether soldiers, miners, or other operatives, than the lack of *espirit de corps* as well as discipline, and a most unfortunate state of things is often brought about by the exercise of mistaken subordinate judgement in opposition to superior instructions definitely laid down. Rules may be technically right or wrong, but a departure from them is only justified under most special circumstances, which were obviously not provided for when the order was given, but individual foresight, and independent action is of course to be commended, and moreover to be expected in the absence of definite instructions.

There is, perhaps, no business which requires more careful management than custom-milling, for the management is constantly confronted with little mathematical problems like these:—If 20 stamps can be run with 12 men, how many men will be required to keep 25 heads on the drop? It is unfortunate you cannot deal with men in fractions except on paper, but it is sometimes possible to solve the problem with a boy. To take another example:—If it costs you 1s. 3d. to cart 1 ton 3 miles on a fine day on a good road, how much will it cost to bring in stone 4 miles on a bush road on a rainy day? To work this out you can reckon that your carts will sink from 6 inches to 18 inches in black soil or mud, as the case may be, a factor of no small consequence to the result.

Very frequent mistakes in deciding upon proper plant and processes have scattered over the world reduction-works of all kinds of which nothing remains but the ruins, though such failures happily are rarer year by year, as more skill and experience is demanded by mine owners in the selection and operation of plants.

The selection of a process, as well as the conduct of it, should be

entrusted to a trained engineer, instead of (as has been too frequently done) leaving it to an amateur; as well put a miner to pick the best fleece out of a flock of sheep!

In the discussion on Mr. Curtis' paper* one speaker remarked on the impossibility of attaching credit to the judgment of managers, like some he instanced who do not consider it worth while enquiring what they are saving or what they are losing, and totally neglect the question of cost; where the ore is shovelled into the battery with a happy disregard of whether it is pounding itself at times to pieces or not. The author heartily coincides with him, but he hopes this will be remedied by more engineers turning their attention to mining; men who can deal equally with the practical, commercial, and technical scientific difficulties of the business, having been alike through the mining school or college, the mine and the mill, beginning of course as assistants or articled pupils,† as it is a grave mistake to suppose that mining can be learnt without a large amount of practical experience of it, both underground and overground, as well as in the office and the shops.

On the other hand, the author has the highest respect and regard for the self-enlightened, self-educated, practical man, than which latter term none in the mining vocabulary is more widely abused or misunderstood. The author knows, personally, men in Australia and elsewhere whom he has the greatest esteem for, who have never had the advantages of a school training, but who were born, not made, engineers, who, by the force of their natural industry, clear perception, and talents, have deservedly raised themselves to the positions in the profession which they occupy and adorn, and he would take the opinion of such men on special points that they have made the study of a lifetime in preference to any other.

They are men, however, who have their heads screwed on the right way, and are of a totally different calibre from the self-assertive, self-advertized, and self-seeking practical man, to whom he has before alluded, who cannot see beyond his natural horizon and scoffs at progress, because in nine cases out of ten he has been brought up neither as a miner nor as an engineer, but has taken to digging late in life, when all other occupations failed.

The author has said enough to show that what applies to labour and management applies equally to machinery and plant, if efficiency be sacrificed to cost; indeed, he should not wonder if the man who framed the

* *Proc. Inst. Civil Engineers*, vol. cviii., page 135.

† The author refers to the system on which colliery engineers are trained, by articling them to a firm of mining engineers in a colliery district.

proverb "penny wise and pound foolish" was a miner who had in his mind's eye the crumbling skeleton of some modern mining company or other which had paid dearly for such a policy in course of time.

One very general mistake to be avoided in milling, as it has ruined more mining enterprises than any other, perhaps, is the erection of a mill, before there is a mine on the spot, sufficiently proved to warrant such a step, *i.e.*, to keep the proposed works employed. Under such circumstances the possession of a mill is a positive disadvantage, as it means, in most instances, that a certain number of men must remain more or less idle part of the time, unless custom ore can be got to keep the requisite permanent staff occupied; under such circumstances it is generally far cheaper to have the ore treated at public crushing mills, if such exist in the neighbourhood.

The writer does not mean, of course, to dispute that the possession of a mill by a private company which can keep it partly, though perhaps not fully at work, does not tend to cheapen production, but the point is that sufficient stone must be supplied by the mine, or from others in the neighbourhood, to keep a certain minimum number of heads constantly employed, and the larger the number, other things being equal, the greater should be the profit. To illustrate the fact that the possession of a mill, if it can be kept moving, assists in cheapening costs the writer would draw attention to a statement made by Mr. L. W. Marsland.* He says (pages 14 and 15): "The point at which quartz ceases to be payable varies, of course, with the circumstances. Thus, in the colony of Victoria at the present time, quartz yielding 10 dwts. of gold to the ton is found to be highly payable, the lodes being of great size. At Charters Towers, the minimum varies considerably. In the great Day Dawn mines 15 dwts. quartz will pay,† as the ore is comparatively free, and the lode (that is to say, the payable portion of it) is very large. As a rule, however, it is understood that, except in the Day Dawn mines nothing under 1 ounce stone will pay; and in some localities such as the Caledonia, it requires a yield of 2 or 3 ozs. to give payable results, the lode being usually very small, and the rock in the walls, which must be taken away to facilitate working the levels, very hard. With the introduction of improved appliances and methods and the consequent reduction

* *The Charters Towers Gold Mines.* Waterlow Bros. and Layton, 1892.

† According to the Report of the Day Dawn P. C. Company for 1891, the cost of mining and milling (excluding general expenses at Charters Towers, £1,348 1s.) came to £1 14s. 3d., equivalent to about 10 dwts. per ton. Including local and London expenses, the author estimates that the company's total costs did not exceed the equivalent of 11 dwts. $18\frac{8}{17}$ grains on an output of 27,416 tons in 1891.

of the cost of mining and milling, it is hoped that the minimum payable return will some day be reduced to such a point as will encourage the working of the many hundreds of reefs on the Charters Towers gold-field, which at present remain unworked, because of their supposed non-payable character."

This statement reminds one of the early days of California.

Dr. Egleston, page 568, remarks: "Prior to the year 1865, it was considered essential that vein matter should yield at least £4 3s. 4d. per ton to be treated with profit, but the introduction of modern machinery has shown that an ore yielding £1 13s. 4d. to £2 1s. 8d. can be mined at great depths and profitably milled when steam is used; and when high-pressure water can be had £1 0s. 10d. is profitable.* Miners' wages are taken at 12s. 6d. to 16s. 8d. per day (10 hours' shifts). Wood for steam costing from 8s. 4d. to £2 10s. per cord, and water-power from 8d. to 1s. 4d.† per ton of ore treated."

A rough division of the gold-bearing quartz-mines of California into three classes may be rationally made.

First, small veins yielding high grade ore in comparatively small quantities whose cost of extraction and milling is £5 4s. 2d. per ton, and the average yield, say about £10 8s. 4d., as an example we may cite the New River district in Trinity County. The quantity of this ore treated amounts to about 5 per cent. of the ore extracted in the state.

The second class would embrace all the large mines, including 75 per cent. of all the ore extracted in the state. The average cost of mining and milling ore of this class, including general expenses, would be about 12s. 9½d. per ton to mine and mill; the Plymouth and the Zeile, on the mother-lode in Amador County, whose ore only assays £1 5s. 9d. to £1 11s. 7½d. per ton, are instances in point. The ore is free milling, carrying 1½ to 2½ per cent. of sulphides which are often very rich, assaying as high as £20 17s. 8d. to £41 13s. 4d. per ton. Shaft-sinking costs £3 2s. 6d. to £3 15s. per foot. Sawn timber £4 3s. 4d. per 1,000 B.M. Round poles 16 feet long, 14 inches to 16 inches in diameter, 12s. 6d. each. Miners wages are 10s. 5d. per day.

The third class, which comprises 20 per cent. of all the ore mined in the state, would include the Bodie, whose grade is rather high, yielding £6 5s. per ton, but expensive to mine and mill on account of the high

* One might even say 14s.

† This is paid to ditch companies, which bring the water long distances.

prices of labour, fuel, and lumber, the average being about £2 10s. per ton. Most of the gold and silver mines of Ingo County may be included in this group.*

We see from this that the cost of mining as well as milling is largely contingent on quantity, but it is equally to be borne in mind that the quantity milled depends more on nature than on man, who, whilst he can control the amount of development (which is a very important factor in the question) is powerless to alter the size and distribution of the ore-shoots in a vein. Mr. Marsland adds to the remarks that have been quoted "Owing to these circumstances the yearly returns of gold from the field, large as they are, cannot be expected to compare with those of other places in other parts of the world, where, in the great majority of cases, the first consideration is quantity of gold without respect to the question of profit! If the same amount of money were expended in the erection of batteries and developing the mines of Charters Towers as has been within the past few years expended on the South African goldfields there would be no difficulty in producing gold at the rate of 100,000 ounces per month."

Now, although Mr. Marsland's statements no doubt apply to the cost in general of local company-mining on the premier goldfield of Australia, as it is sometimes called, other companies as well as the Day Dawn, can mine and mill below the average Mr. Marsland gives, but mostly the English companies, which possess batteries of their own. The Bonnie Dundee and Mosman for example (both under excellent management) should be able to give a good account of themselves, but in proof of this assertion the author will again take the New Queen and Disraeli for illustrations.

Both these companies possessed mills of their own when the author was in charge of them, and their evidence is the more valuable as regards cost of mining, because they represent two opposite cases in the same locality.

The one (the Disraeli) affording an example of a very wide lode formation, 15 to 40 feet wide, carrying irregular bunches of ore, thrown

* In the Transvaal, some of the large mines on the Randt make 10 dwts. pay. At Barberton, the cost of Sheba gold is said to be £1 4s. per oz. obtained (the ore averaging 1 oz. 12 dwts. 22 grains.) In Mysore (where fuel is costly, and the climate is liable to disorganize the native labour at certain seasons when cholera is prevalent) the cost is said to be about £1 18s. 10d. per oz. of gold extracted (the ore averaging 1½ to over 2 ozs. per ton). The actual mine charges at Nundydroog however were less than this, in 1891 amounting to £2 14s. 8½d. per ton.

sometimes to the hanging, sometimes to the foot wall,* which next to an extremely narrow lode, jambed in between hard walls, is certainly the most expensive and variable class of ground to work. The solid feet of ground that must be stoped to yield a certain tonnage being of course greatly in excess of the ore it would represent were the mineralized portion of the vein regular and compact, which all entails extra cost in winning as well as exploratory and dead-work.

The other case, the New Queen cross-reef, is a fair example of a Charters Towers vein, a well-defined quartz lode, averaging from 6 inches to 3 feet in thickness,† with well-defined walls of syenite.

Of course the actual cost of stoping in any two instances, apart from the size and nature of the lode, length of ore-shoot, quality of labour, general management, and character of explosives used, will depend on the system on which the mine is laid out, the ground is removed, ventilated, drained and supported, and the relative perfection of the haulage and other mechanical arrangements for saving labour.

The cost of development and exploratory work, is also liable to still wider fluctuations, and nothing affects the cost of mining more than the proportion which this bears to the producive work (depending on the nature of the lode, and scale of operations), as it obviously stands in inverse proportion to the tonnage of ore that a given area of ground will yield, and varies with the mining experience and judgment of the management; if the factor of luck in exploitation is excluded from the result. More money can be saved or wasted in fact by good or bad judgment in regard to the probabilities of ground, and the method of proving it, than in any other way; the matter rests solely on the mining knowledge of the superintendent and mine captain, based on a sound or unsound acquaintance with the practical problems of applied geology, as bearing upon ore-deposits of different kinds. A knowledge of those branches of geology which deal chiefly with the igneous crystalline and metamorphic rocks, the distributions and occurrence of ore deposits under different conditions; the phenomena of structure and of faults as they variously affect veins is of the utmost benefit and importance to the metal-miner.‡

The cost of exploration and development§ in the case of the New

* Report of Mr. C. P. Purinton, page 5.

† Manager's Report, August 27th, 1888.

‡ In the exploration of mineral ground, the lack of detailed knowledge such as this is likely to prevent the best advantage being taken of natural conditions in laying out the work, and providing for the most economical extraction of the ore.

§ The distinction between the two terms is determined by the shaft, level, or winze being in ore-bearing (payable) or barren (unpayable) ground.

Queen cannot be given as it has not been published, but we can take it at what ought to be a liberal allowance at Charters Towers under similar circumstances to those above stated.

Assuming that each foot of level and winze driven develops or explores an amount of ground equal to 1 foot in length multiplied by half the depth or length of the block on each side of the drivage, multiplied by the average width of the lode between the next adjacent levels and winzes, or the points where such would ultimately be driven or sunk; at the ruling rates of sinking and driving in the district one may reckon that the cost of development and exploration in a reef of the kind described ought not to exceed 7s. 6d. to 15s. per ton on an output of 270 to 500 tons a month.

The cost of mining 1,086 tons (on an average of 270 tons stoped per month) is given in the author's report, dated January 31st, 1889, published by the New Queen company, as £1 8s. 2d. per ton, to which must be added a charge for general expenses, which may be placed* at, say 2s. 5¼d. to 5s. 1¾d., reckoning 270 to 500 tons mined and milled per month.

With regard to the Disraeli mine, taking six months' working, during which 525 tons of ore were won monthly, the cost of stoping may be reckoned approximately at £1 11s. 5d. per ton, but the cost fell to 18s. 6d. per ton, breaking 750 tons a month, during two months in 1887. The underground work was under the immediate charge of Capt. Thos. Blaney, a most competent miner, and all round man.

The cost of dead-work and exploration for the same periods and outputs may be taken at 17s. 2d. to 9s. 3d. per ton, to which we must add, say 6s. 3d. to 3s. 4d. for management and general expenses, which should be a liberal allowance.

The cost in the two cases might be therefore calculated relatively as follows:—

	Disraeli. Ore Mined per Month. Tons. 525 £	s.	d.	Tons. 750 £	s.	d.
Development and exploitation	†0	17	2	†0	9	3
Mining (stoping)	†1	11	5	†0	18	6
Milling 890 tons per month	‡0	9	2	‡0	9	2
General expenses	§0	6	3	§0	3	4
Total cost (estimated)	£3	4	0	£2	0	3
	Dwts.	Grs.		Dwts.	Grs.	
Equivalent in dwts. to the ton	18	17$\frac{23}{41}$		11	18$\frac{29}{41}$	

* Company's Annual Statement of Accounts to June 30th, 1890 and 1891.

† See pages 100 and 101. ‡ See Table II. § Proportions assumed.

	New Queen. Ore Mined per Month. Tons. 270 £ s. d.			Tons. 600 £ s. d.		
Development and exploitation	*0	15	0	‡0	7	6
Mining (stoping)	*1	8	2	‡1	0	0
Milling 852 tons per month	†0	12	2	†0	12	2
General expenses	*0	5	1¾	*0	2	5¼
Total cost (estimated)	£3	0	5¾	£2	2	1¼
	Dwts.	Grs.		Dwts.	Grs.	
Equivalent in dwts. to the ton	17	$16\frac{34}{41}$		12	$7\frac{31}{41}$	

Reckoning a pennyweight of Charters Towers gold, as being worth 3s. 5d. on the average, it will be noticed that in the cases given the cost does not come up to Mr. Marsland's general assumed average, and it would be very considerably less on a larger tonnage mined and milled.

It would be a step in the right direction towards making mining more of a business and less of a speculation, if mining companies more often charged and set aside a fixed sum annually for depreciation of the mine, as well as for redemption of capital spent on plant.

Some of the South African companies pursue this sound and proper business policy on the basis that the ore in sight must redeem the cost of its development, for instance, supposing 135,081 tons standing in sight against £24,814 14s. 3d. spent on development for 12 months, a charge of 3s. 8d. per ton would be debited against the stone milled in the year. This is a good policy since mines may, and often do, in fact, become poorer in depth, which may happen in two ways, either by a diminution in the value of the ore, or a reduction in the size of the ore-bodies.

The mine owner is generally anxious to hurry forward the erection of a mill too precipitately, because he knows it is the requisite first step towards making profit at all, unless he can ship his ore, or treat it elsewhere; but what is the result? In some cases it is found, after a large capital outlay has been thrown away, that no mine, worth speaking of as such, exists, and the glowing reports made by some so-called expert, on the faith of which the money was subscribed, turn out worthless. In others, the money which should have been invested first in mining exploration and development is expended on surface improvements, owing frequently to insufficient preliminary investigation and consideration, and the consequent failure to provide adequate working capital. An insufficient balance consequently being left to open-up what might have turned out a paying property, with the result, that the shareholders, tired of calls without returns, refuse to subscribe more money.

* See pages 100 and 101. † See Table II. ‡ Proportions assumed.

In many such cases, if the funds raised at first had been expended on the mine, the profit from the sale of the ore would have sufficed to erect the plant afterwards, and the investment would have been saved from failure, or at any rate there would be the satisfaction of knowing that the mine had been thoroughly tested as far as circumstances permitted and found unable to pay, and in such a case a useless waste of capital would be avoided.

It is perhaps a hard matter for an engineer who has to prepare preliminary estimates to avoid running one of two risks. Either he is liable to underestimate, in which case the company finds itself, as already mentioned, without sufficient funds to complete what it has undertaken to do ; or he must allow a certain margin at the risk of being considered extravagant. But the latter course is really the safer risk of the two, and it is the best guarantee, in point of fact, that the interests of his employer is his first consideration.

Mr. H. D. Hoskold* remarks, "It will always be found as a rule that to err on the side of excess of size of machinery . . is far better than defect." Alluding to natural or artificial means of draining a mine, he also adds: "The allowance to be made must depend upon the requirements of the case, and the judgment and capabilities of the engineer in charge of the execution of the works, but it is not unfrequently the case that the hands of a good man are completely tied by the control exercised by a board of directors, who, perhaps for the first time, may have engaged in mining. Such interference is most absurd, and occasionally proves very ruinous to the shareholders, because a really good and efficient man could not work under such restrictions." What applies to the matter in question is relevant to many other branches of mining, where capital outlay is involved.

"A few of the failures† were the result of speculations for purposes not strictly honest, but they have all brought mining more or less into discredit as a haphazard investment, when in reality with the same foresight, prudence, and management which is given to other commercial enterprises, mining and milling would pay more than double the legitimate profits of ordinary business." Three things only are necessary, the co-operation of the capitalist, the miner, and the engineer for one common object—to advance legitimate mining. United, their power to do so may be compared with a treble-force detonator, separate them, and their useful effect is reduced to the power of an ordinary cap.

* *Engineer's Valuing Assistant*, page 10. † Dr. Egleston, *Silver*, page 445.

Speaking generally, the proper process to adopt is that which all things considered, will yield the largest possible commercial profit, a point it is the business of the mining engineer to determine; but one thing is perfectly certain, the process not to adopt, is that which leaves any doubt whatsoever, whether there will be any commercial profit at all.

Profit and economy in the conduct of business on a large scale, such as most large mining corporations demand at the present day, requires capital, combined with business tact and organisation. The secret of the success of American mining ventures, lies in six facts :—

(1) Americans treat metal mining as a business, that is to say, they purchase mining property first-hand on an investment basis, not as a mere share-gamble, a condition of things brought about by the efforts of mining men and the mining press, a tendency we have commenced to follow in England only in recent years to any marked extent.

(2) They are not afraid of risking a large capital outlay to obtain a a big return.

(3) They carefully estimate the chances before embarking in a new proposition, and if they lose by their own want of judgment, they do not blame their manager or engineer, unless he is the responsible person, but pocket their experience and try again with hopes and prospects of better luck, aided by better knowledge. The difference in fact between the company promoter and the capitalist, whether English or American, who interests himself in *bona fide* mining, is that one does justice to his property and his employees; the other does not care a red-cent either for the industry or the men engaged in it, so long as he can "boom his stock," a very proper object, no doubt, providing the shares are worth it.

(4) They are open to adopt any improvement demonstrated to be such, no matter what the first cost, so long as it tends to cheapen production in the long run.

(5) They minimise their risks of loss by developing promising prospects, rather than financing worked out mines, and multiply their chances of profit as much as possible, *i.e.*, avoid trusting all their chickens to one hen.

(6) They will bid and give a high figure for the highest technical and manual skill obtainable in any special province where it is needed, and it therefore pays to employ such; a principle which people in other parts of the world with post-dated ideas and less foresight would call extravagance, but which, with good business judgment, is in point of fact, the very essence of economy.

Table IV. summarizes various particulars already given, in connexion with which the author has to acknowledge the kindness and trouble taken by a number of his friends and members of the profession in aiding him with every information in their power, but owing to the difficulty of collecting particulars with regard to actual gross cost of different classes and sizes of plant, cost per ton of treatment by different processes, and losses in treatment, he regrets that the scope of this table cannot be still further enlarged.

The writer will be thankful to receive, and will gratefully acknowledge, any information or criticisms which will enable him to extend, revise, or perfect its individual details.

He ventures to say that at the present time it is impossible for any private individual to get complete particulars of the kind, in twenty or even ten instances that would illustrate each process, if the whole world were prospected for data.

It is to the interest of all mining-undertakings that such information should be forthcoming, because anything that tends to a knowledge of these matters is a step towards cheapening mining generally, to the advantage of each individual company engaged in its pursuit, and the industry as a whole.

It is not too much for shareholders in mining companies to expect an annual statement of the working costs per ton, subdivided under such general heads, as have been mentioned. If such particulars are not obtainable it is usually, let us hope, from unconsciousness of the importance commercially, to the stockholders, or otherwise one is forced to the conclusion that the oversight is due to defective management or business direction, or else that owing to other causes the affairs of a company will not bear the search-light of open investigation.

In the Colonies and America, much is done by the various governments in the way of collecting statistics of working; but without attempting in any way to pry into the private concern of individual profit and loss, there is still room for doing more, as is evident from the paucity of information on some of the points that the author has touched upon.

Statistics can be made complete without being unduly voluminous, and their collection is well worth the attention of English mining companies and engineers engaged in metalliferous mining abroad.

To make them of practical value it is necessary that, however, they should be collected on the same system. The following table is mostly a summary of facts previously stated :—

TABLE IV.

Process.	General Nature of the Ore Treated.	Daily Capacity of the Works.	Approximate Average Cost of Treatment per Ton. Lowest.	Highest.	Metal or Mineral Saved.	Saving Effected.* Lowest.	Highest.
		Tons.	£ s. d.	£ s. d.		Per Cent.	Per Cent.
Concentration	Heavy pyritic ores	70—800	E. 0 0 10 A. 0 1 1¾	0 11 10 0 12 6	Blende & galena, copper... ...	60	99
Smelting	Lead, argentiferous and frequently auriferous? ...	24—96	A. 0 12 6	6 5 0	Silver and gold... Lead	90‖ 85	98 95
Chlorination—Vat	Pyritic concentrates... ...	3½—9	A. 0 14 9½	4 3 4	Gold ... ... Silver	90 60	94 65
Barrel	Pyritic concentrates and occasionally "crude ore" ...	2—4 50—200	A. 0 11 10½	3 0 10½	Gold ... ... Silver	92 60	97 65
Cyanide process	Pyritic gold concentrates, tailings, and crude ore	50—250	A. & S. 0 6 10½	2 10 0	Gold ... ... Silver	65 70	84·5 80
Raw grinding	Pyritic gold concentrates §... Pyritic gold ore	2¾—3 20	S. 1 8 5½ E. 0 8 10	2 16 11 ?	Gold and silver	40 78 7	80 91·7
Washoe pan process ...	Pyritic silver tailings carrying gold	150	A. 0 10 3¾	1 6 0	Gold ... ... Silver	25 75·8	42·5 85·8
Pan-amalgamation — Roasting ...	Complex milling ores of silver	20—240	A. 1 13 4	3 2 6	Gold ... ... Silver	40 65·3	60 94
Pan-amalgamation — Dry... ...	Free-milling silver ores	30—100	A. 1 5 0	2 11 0	Silver	70	85
Pan-amalgamation — Wet... ...	Free-milling silver ores		A. 0 12 6	1 17 6	Gold ... ... Silver	45 60	60 80
Boss process	Combined gold and silver ores	120	A. 0 12 6	2 1 8	Silver and gold...	75	85

A.—America. E.—Europe. F.—Africa. I.—India. M.—Mexico. N.—South America. S.—Australia. W.—Wales. * Careless or ignorant management may of course entail larger losses than those given. † Stamps. ‡ Huntington Mill. § With a small alloyage of silver. ‖ Under most unfavourable circumstances.

TABLE IV.—*Continued.*

Process.	General Nature of the Ore Treated.	Daily Capacity of the Works.	Approximate Average Cost of Treatment per Ton.		Metal or Mineral Saved.	Saving Effected.*	
			Lowest.	Highest.		Lowest.	Highest.
		Tons.	£ s. d.	£ s. d.		Per Cent.	Per Cent.
Plate amalgamation— (1) With concentration and grinding ...	Ores containing free-gold and pyrites	20—160	S. & I. 0 3 0¾	0 14 6	Gold	45	87·6
(2) With concentration and chlorination or smelting of the concentrates	Ores containing free-gold and pyrites	80—130	A. { 0 1 5½ 0 3 3	? ?	Gold ... ... Silver	92 70	93·8 74
(3) Without concentration	Free-gold ores	70—700	W.A.& F.†1/4½, ‡1/0½	0 15 7¼	Gold	70	94
Lixiviation— Russel process	{ Complex silver ores free from *much* lead or copper }	75	A. 1 6 3	2 10 4	Silver, etc. ...	82	91·9
„ raw leaching ...	Tailings (raw or roasted) ...	25—75	A. 0 6 10½	0 19 4	Silver	55	60
Ordinary lixiviation ...	Complex silver ores	50—100	{ M. 0 15 5 A. 1 0 6	? ?	} Silver	67	85
Patio process	{ Rich silver ores, containing traces only of lead and zinc	10—19	M. 5 4 2	5 14 11	{ Silver ... ... Gold	70 60	90 ...
Tina process (modified)	Complex silver ores	8	N. 1 8 7½	...	Silver	...	60
Modified Tina & Fondo (Bolivian)	{ Docile silver ores ... ... Base silver ores	8 8	N. } 1 17 6 N. }	...	{ Silver ... ... Silver	92 80	96 85
Pyritic smelting ...	Complex silver and gold pyritic ores	100	A. 0 12 6	?	Silver and gold...	?	96

A.—America. E.—Europe. F.—Africa. I.—India. M.—Mexico. N.—South America. S.—Australia. W.—Wales. * Careless or ignorant management may of course entail larger losses than those given. † Stamps. ‡ Huntington Mill. § With a small alloyage of silver. ‖ Under most unfavourable circumstances.

(To be continued).

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN THE ROOMS OF THE PHILOSOPHICAL SOCIETY OF GLASGOW AND OF THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND, 207, BATH STREET, GLASGOW, SEPTEMBER 6TH, 1893.

MR. GEORGE LEWIS, RETIRING PRESIDENT, IN THE CHAIR.

The CHAIRMAN said he might safely congratulate not only the Mining Institute of Scotland but also the Federated Institution of Mining Engineers on their recent union. He need not say how desirable it was to have an interchange of ideas between mining engineers from the various mining districts of Great Britain. During the past year many papers had been contributed of a very valuable character, and the *Transactions*, he thought, reflected great credit on the members of the Institution.

The SECRETARY read the annual report of the Council for the past year, as follows :—

THE FOURTH ANNUAL REPORT OF THE COUNCIL.

The Council are again enabled to congratulate the members upon the success which has attended The Federated Institution of Mining Engineers during the year.

The objects of the Institution are well known, but the members could materially increase its prosperity by promoting its claims and advantages and extending its membership. The leading advantage of the Institution is that members receive the papers read at the meetings of the Federated Institutes, and, in addition, participate on equal terms at the two General Meetings held in each year in rotation in the district of each Institute, and one annually in London.

The influence of the Institution would become more effective and the value of its *Transactions* greatly enhanced if it included all the societies interested in mining, metallurgy, engineering, and their allied industries. The Council would therefore urge members who may be interested in other kindred societies to use their influence in favour of federation.

The Mining Institute of Scotland applied to the Council during the course of the year, and was admitted from August 1st, 1893, into the Institution, which now includes six societies, viz.:—The Chesterfield and Midland Counties Institution of Engineers; the Midland Institute of Mining, Civil, and Mechanical Engineers; the Mining Institute of Scotland; the North of England Institute of Mining and Mechanical Engineers; the North Staffordshire Institute of Mining and Mechanical Engineers; and the South Staffordshire and East Worcestershire Institute of Mining Engineers.

The following table shows the progress of the Institution since its formation on July 1st, 1889:—

Year.	No. of Members.	No. of Non-Federated.
1889-90	1,189	50
1890-91	1,187	9
1891-92	1,414	19
1892-93	1,533	19

The number of members for the year 1893–94 will be considerably augmented by the accession of the Mining Institute of Scotland.

The Council have considered the status of the admission of members, and have suggested to the Federated Institutes the desirability of adopting a classification of their members in accordance with Bye-law 8 of this Institution.

General Meetings during the year were held in North Staffordshire, Derbyshire, and London, when papers of considerable interest were communicated. The thanks of the Institution have been conveyed to the gentlemen who kindly allowed their works and collieries to be visited by members during the period of these meetings. The attendance of members at the General Meetings has been satisfactory, notwithstanding the fact that they reside in all parts of the kingdom and abroad.

Presidential addresses have been delivered during the year to the members of the Federated Institution of Mining Engineers by Mr. George Lewis; the Chesterfield and Midland Counties Institution of Engineers, by Mr. Alfred Barnes; the Midland Institute of Mining, Civil, and Mechanical Engineers, by Mr. W. E. Garforth; and the North Staffordshire Institute of Mining and Mechanical Engineers, by Mr. R. H. Cole.

The papers contained in the *Transactions* during the year refer to subjects of both general and special interest, and the Council trust that the members will send in their contributions as liberally as heretofore.

There have been the following papers on subjects connected with mechanical engineering:—

"Steam Boilers with Forced Blast: the Perret System for Burning Dust and Rejected Fuels; with Notes on Testing Boilers." By Mr. Bryan Donkin, Jun.

"The Wear and Tear of Steam Boilers due to Expansion and Contraction-strains." By Mr. J. Clark Jefferson.

"The Lockett and Gough Direct-acting Pump." By Messrs. James Lockett and — Gough.

"Joseph Moore's Hydraulic Pumping Arrangement." By Mr. R. T. Moore.

The ventilation of mines and the subject of safety-lamps have been discussed in the following papers:—

"Experiments upon two Guibal Fans at St. John's Colliery, Normanton." By Mr. Edward Brown.

"Manometric Efficiency of Fans." By the Rev. G. M. Capell.

"Observations on Fans of Different Types working on the same Upcast Shaft." By the Rev. G. M. Capell.

"A Portable Safety-lamp with Ordinary Oil Illuminating Flame, and Standard Hydrogen-flame for Accurate and Delicate Gas-testing." By Prof. Frank Clowes.

"Experiments upon a Waddle Fan and a Capell Fan working on the same Mine at equal Periphery Speeds, at Teversal Colliery." By Mr. J. C. B. Hendy.

"On Earth Pulsations and Mine Gas." By Prof. John Milne.

"The Estimation of the Actual Effective Pressure or Water-gauge in the Ventilation of Mines." By Mr. T. A. Southern.

a large capital, but the direct opposite may be said of a mine in its infancy, working on a small scale, with a small production, which generally means a small net profit. A staff of highly skilled and consequently highly paid officials would obviously be its ruin. It is therefore, fortunate that it is only when a mine reaches a certain size and depth, with a corresponding output, that the services of a skilled staff become indispensable to commercial profit on a large scale. There is a miners' saying that tributers will make a living where a company will starve, and there is a great deal of truth in it, if only because tributers have no general expenses to bear.

In the mining and milling of gold and silver ores, speaking from the writer's own experience, the skilled Anglo-Saxon workman, whether he be British, American, or Colonial, distances all competitors. Each subdivision of the race numbers in its ranks hundreds of miners (using the expression as covering mill-work as well) second to none in the world, though not a cheap man certainly. The payment of a low rate of wage to the skilled workman is by no means the only, or indeed the most expedient means of lowering the cost of production, since the cost of a day's labour in any responsible occupation is in reality in inverse proportion to the intelligence as well as the sinew and endurance it represents, and in reducing the rate of the one you run great risk of lowering the standard of the other, so long as superior skill can command better wages elsewhere.

The writer's contention is that the cheapest skilled labour is not always, indeed is very rarely, the most economical, if only because the highly-paid man is the most contented, better fed, and better housed man, and the author proposes to show that it is quite possible to cheapen costs without lowering wages, providing a reduction in working expenses is not demanded suddenly, whether by strikes or market fluctuations. To illustrate this,* the Atlantic mine, in Michigan, which produced native copper from 1873 to 1877, scarcely made ends meet, and had to levy calls; since then, with the price of copper steadily declining, and also the yield of the ore, the cost of mining has been so greatly reduced that the company has made a profit every year. The workmen, who earned on an average from £10 8s. 4d. (50 dollars) to £12 5s. 10d. (59 dollars) a month in 1873, continue to earn almost as many dollars, and owing to the greatly reduced cost of living they are now very much better off and save really more money than they did twenty years ago.

* These particulars are taken from a leader on "The Free Coinage Question," in the *Engineering and Mining Journal* (New York), vol. lii., page 497.

The chief items of cost at the Atlantic mine for three years are shown in the following table:—

	1873.	1880.	1890.
Tons treated	51,048	169,825	278,300
Pounds of ingot produced	863,366	2,423,225	3,619,972
Percentage of yield	0·81	0·71	0·65
Average selling price, cents. per lb. ...	26·66	20·55	15·21
Cost of stoping per fathom	$22·28½	$14·35	$4·21
„ driving per foot	19·09½	12·90	5·10
„ sinking shafts per foot	38·03	18·04	22·90
Cost per ton, mining and all surface expenses, taxes, etc.	5·12	2·14	1·04
Cost of transport, 3 miles from mine to mill, per ton	0·15	0·09½	0·03½
Cost of stamping and concentrating ...	1·05	$0·38^{18}$	$0·27^{78}$
Cost of freight, smelting, marketing, and New York office, cents. per lb.	$0·34^{9}$	0·33	$0·20^{37}$
Total expenditure per ton of rock treated	8·26½	2·47	1·67
Net profit per ton of rock treated	...	0·22	0·29¼
Loss do.	4·53	...	...

It would appear from this table, that since wages have practically remained unchanged, or are in fact higher (considering what they will purchase), the reduction in the cost of producing copper is due to improvements in mining, in stoping, in drifting, and through the use of rock-drills, high explosives, and other modern improvements, reductions in freight charges, in milling, and concentrating, in smelting and marketing, due to improved systems of doing the work.

All this shows that improved processes, greater facilities for the distribution of products, and greater skill and economy in the management of business have brought about the lower prices of recent years, and with them have added to the general prosperity.

If you look for the cause of these developments of the practical science of mining, it may be traced largely to technical education, the development of technical societies and technical literature. Mr. John Birkinbine, in his presidential address at the Montreal meeting of the American Institution of Mining Engineers,* states that there are to-day in the United States four engineening societies of a national character, with a membership as follows:—

	Founded.		Membership.
Society of Civil Engineers	1865	...	1,650
Institution of Mining Engineers ...	1871	...	2,400
Society of Mechanical Engineers ...	1880	...	1,650
Institution of Electrical Engineers ...	1886	...	650

* *Trans.*, vol. xxi., page 962.

A few facts selected from many which could be mentioned, illustrate the progress made during the existence of the American Institution of Mining Engineers from 1871 to 1893. The annual output of iron ore has increased from 3,000,000 to over 16,000,000 gross tons. One and two-thirds million gross tons of pig-iron was the output of the blast furnaces of the United States at the birth of the American Institution. Last year shows a total of over 9,000,000 gross tons, while, owing to improved construction and methods, a smaller number of furnaces yield the larger quantity of pig iron; three-quarters of the American product being produced with coke. The growth of the American steel industry is not less remarkable, and the enquiry might be carried further into the manufacture of rails, plate and bar-iron, and steel nails, cars, machinery, and great works fitted with superb appliances for fabricating them. The statement that a ton of pig-iron, of bar or plate-iron, or a keg of nails now sells at from 33 to 40 per cent. of what was received for it in 1871, whilst the price of steel rails is but 25 per cent. of what these commanded in 1871, is an eloquent commentary on the debt mining owes to the development of scientific principles by mining institutions. In 1871, the greatest depth which had been reached in any of the Lake Superior copper mines was 1,000 feet, and the price of copper stood at 30 cents and upwards, yet it was then impracticable to work those mines which did not produce mineral carrying 2 per cent. or more of copper. At the present time there are mines in the same district 4,000 feet deep, and with copper selling for 12 cents per pound, mineral yielding 0·6 per cent. is raised from a depth of 2,000 feet, crushed, jigged, and delivered at refining works, and sold at a moderate profit on the operation.

The hydraulic elevator and the deflector applied to hydraulic mining are inventions of great practical importance, which only date back, the one to 1870, and the other to 1876, and, under favourable conditions, gold-gravel has actually been hydraulicked for as low a sum as 3 cents per cubic yard. Figures will be found in this paper which illustrate the advances that have been made in reducing the costs of quartz mining, and improving the extraction of gold, etc., by chlorination and concentration.

Pan-amalgamation for silver-ores has been bettered and cheapened, and silver-lixiviation, direct matte-smelting, and the cyanide process are all modern processes born of scientific enquiry, which have made important advances and are likely to bear yet better fruit. Silver-lead smelting has been greatly developed, the so-called practical smelter having given place to the chemist and lead-metallurgist, cleaner and better work is now

done than formerly, lower-grade lead-ores are utilized, and lead-slags made in 1878 are now being re-worked.

Advances have been made in the utilization of electricity, the producfion of aluminium, and a host of other directions for which the world is indebted to the efforts of members of societies like those named in the United States, the various branches of the Federated Institution of Mining Engineers, which numbers over 2,000 members, the Iron and Steel Institute with 1,500 members, the Institution of Civil Engineers with 6,000 members, the Institution of Mechanical Engineers, of about the same size, and similar institutions in Germany, France, and other parts of the world working for a common object.

Any union for mutual advancement commands esteem, so long as the better element of membership is not hidden or overruled by selfish purposes controlling the administration of affairs to the disadvantage of its mutual progressive features. A past president of the Iron and Steel Institnte, alluding to the visit of that Society to the United States in 1890, expresses, the writer thinks, the mission and achievments of technical associations for the advancement of engineering, and of mining and metallurgical knowledge, in words which may be appropriately quoted:—"The expeditions, through which we meet eye to eye and voice to voice our friendly competitors, to discuss the interests and the scientific aspects of the industry which absorbs us, has been of great personal and national benefit. It is thus we learn how much has been accomplished by persistent and intelligent labour, how much remains to be achieved, and how, by the free exchange of ideas, and of productions, friendly understanding is promoted, and personal acquaintance is built up."

The author's fifth proposition (the influence of quality and price of supplies, etc., used upon the cost of milling) needs no demonstration, but in regard to the sixth and seventh (the power employed and the situation of the works), the Disraeli and New Queen mills will once more serve as illustrations, the former showing an economy both in cost of fuel and transport. (Table II.) This may be partly explained by the Disraeli boilers being of tubular pattern, and being run up to their full capacity, avoiding waste of surplus steam,* and as regards

* At the New Queen and other Charters Towers batteries, Cornish and Lancashire boilers are almost exclusively used, owing to the character of the feed-water which incrusts the tubes; and at the former mill (as is often the case) the engine-power is largely in excess of the immediate requirements, being intended to provide for any enlargement of the plant.

transport, the Rishton works enjoyed the advantage of a tramway between the mine and mill. Of course where water-power is available it offers a large saving over steam. Taking the total actual net difference in the cost of milling at the two mills, viz: 3s. per ton attributable to the natural advantages of location, and other causes that have been pointed out, if the one mill has actually cost let us suppose £3,000 more than the other to erect, it is certain that on a steady output of 40 tons per diem, it would have paid this sum back with interest in less than two years by effecting a saving of £1,480 to £1,780 per annum, or about £125 to £150 per month.

There is a good deal also to be said about the eighth factor in the case (the efficiency of the general management), as it is the master-key to the whole business.

If the workman is to demand and obtain high wages in the future it will only be by employing high-class technical and business skill in the management and conduct of operations, so as to take advantage of every practical scientific improvement which tends to cheapen the aggregate cost of production, whilst duly proportioning wages in all departments to relative efficiency and usefulness, whether in respect of mental attainments or manual dexterity. Unskilled labour can no more hope to compete with skilled workmen living in comfortable circumstances (though they be highly paid), in a field where skill is required, such as mining, than the skilled workman can expect to banish cheap labour from a field where nothing but slight manual effort and intelligence are needed.

We have seen that the difference between the cost of working in one mill as compared with another depends on its design, location, quantity and kind of ore put through it in a given time, the number and character of the external appliances for catching gold or other metal after it leaves the crushing machinery, the cost of fuel, labour, and supplies, the power available, and the organization and *personnel* of the staff, which directly depends on the general management. In regard to this last essential the gross cost of operations is nothing to gauge it by, the only certain proof of efficiency and economy is the ratio which the cost of handling and treating a given tonnage, bears to the percentage of gold or other metal saved when compared with other parallel cases.

Technical skill, combined with business management, in dealing with material and with men is absolutely necessary nowadays for the regulation of work, as the general efficiency of the staff as well as the expenditure on supplies, etc., depends upon it. Discrimination in employing the right man and the proper material in the right place, is the pivot upon

which management turns, though it amounts in the former case simply to a knowledge of the time when to put on an extra man at a profit and when to knock one off the pay-sheet, where to employ a mechanic and where to make shift with a labourer—a knowledge only to be gained by experience of men and materials.

Where you have to deal, as you must in any large mining undertaking, with the three different factors of brain, manual skill, and muscle, it is not less ridiculous for instance to place a man, who may be perhaps an adept at spalling stones, in charge of a mill at the salary of a first-class foreman, than it would be to put the latter to cob ore at the wage of a labourer.

Engineering knowledge and business capacity are co-essentials in selecting as well as in managing modern metallurgical processes and mining enterprises. The capitalist who fails to recognize this "knocks a nail from the inside into his own coffin." The miner who does the same, throws a stone at the only bird which can lay "the high-priced golden egg," where, as in some localities, the sum of his daily wage amounts perhaps to a half-guinea or more.

No one can doubt that the question of mutual and fair adjustment between the two co-important trade factors of capital and labour so as to enable both to exist in harmony, is fast becoming the burning problem of the hour, as it certainly will be of the next decade, or at any rate the next century, and it is certain that the prop upon which the very existence of the miner and the capitalist mutually depends is science practically applied. The miner who thinks otherwise is simply footing his stulls on treacherous ground, which will sooner or later break away with him, and entomb himself and his mates in the *débris*, whilst, as for the guinea-fowl who selects the board-room merely for a roosting place, he will equally promote his own extinction, becoming with the decay of all mining enterprise worth the name like "the dodo."

Messrs. McDermott and Duffield remark*:—"It is not possible to supply the lack of skill and experience by instructions and the owners of mills should take the only safe course in this part of the business by employing a good mill-man who has a record of successful work elsewhere. The owners of a mine or directors of a company may be impressed by the bearing and talk of an applicant for the position, but the frequent and lamentable failures resulting from this method of choosing a mill-man are proof of its inadequacy. Testimonials as to character and experience need just as much examination as the applicant

* *Gold Amalgamation*, page 13.

"An Improved Water-gauge." By Mr. A. H. Stokes.
"A Safety-lamp with Standard Alcohol-flame Adjustment, for the Detection and Estimation of small Percentages of Inflammable Gas." By Mr. A. H. Stokes.
"The Coad Electric Miner's Lamp." By Mr. Henry White.

The geological papers have been:—

"The Correlation of the Coal-fields of Northern France and Southern England." By Prof. Marcel Bertrand.
"Mining in New Zealand." By Mr. George J. Binns.
"Practical Notes on the Geology of Wirral." By Mr. W. Fairley.
"The Work of the Geological Survey." By Sir Archibald Geikie.
"Geological History of the Rawdon and the Boothorpe Faults in the Leicestershire Coal-field." By Mr. W. S. Gresley.
"Notes on the Occurrence of Manganese Ore near the Arenigs, Merionethshire." By Mr. Edward Halse.
"The Gold-bearing Veins of the Organos District, Tolima, U.S. Colombia." By Mr. Edward Halse.
"The Geology and Coal-deposits of Natal." By Mr. R. A. S. Redmayne.
"The Coal-fields South of Sydney, New South Wales." By Dr. James R. M. Robertson.
"Auriferous Conglomerates of the Witwatersrandt." By Mr. F. G. Shaw.
"Coal: its Varieties and Application to Manufactures and the Arts." By Mr. Richard H. Wynne.

Mining engineering has been the subject of the following papers:—

"Use of Cement in Shaft-sinking." By Mr. Bennett H. Brough.
"Arrangements for Sinking to the Whinmoor Seam from the Silkstone Seam at the Tankersley Collieries." By Mr. W. Hoole Chambers.
"Fire-setting: the Art of Mining by Fire." By Mr. Arthur L. Collins.
"The Opening-out and Working of the Rearer Coals of North Staffordshire." By Mr. Ernest Craig.
"A Combined Centre-line Apparatus." By Mr. William Foulstone.
"Notes on an Earth Explosion or 'Bump' at Hamstead Colliery." By Mr. F. G. Meachem.
"The Mineral Oil Industry of Scotland." By Mr. Robert Thomas Moore.
"The Support of Buildings." By Mr. W. Spencer.
"Waste of Coal." By Mr. James Tonge.
"Gold-mining in Brazil." By Mr. E. M. Touzeau.
"The Longwall Method of Working as applied to Seams of Moderate Inclination in North Staffordshire." By Mr. Edward B. Wain.
"Queensland Coal-mining, and the Method adopted to overcome an Underground Fire." By Mr. Edward S. Wight.

The spontaneous combustion of coal was considered in three papers, which have led to valuable discussions:—

"The Spontaneous Combustion of Coal." By Mr. Herbert W. Hughes.
"Spontaneous Combustion in Coal-mines." By Prof. Arnold Lupton
"Spontaneous Combustion in Coal-mines." By Mr. Joel Settle.

Other papers have been contributed as follows:—

"The Use of Petroleum, Paraffin, and other Mineral Oils Underground." By Mr. W. N. Atkinson.

"Description of the South Dyffryn and Abercanaid Collieries." By Mr. E. J. Bailey.

"The Extraction of Magnetic Particles from Auriferous and other Ores." By Mr. Walter B. Bassett.

"Engineering Scraps in Australian Coal-mining." By Prof. W. E. Benton.

"An Improved Head-gear for Pit Horses." By Mr. G. J. Binns.

"Barometer, Thermometer, etc., Readings for the Year 1892." By Mr. M. Walton Brown.

"The Manufacture of China and Earthenware." By Mr. W. Burton.

"The Choice of Coarse and Fine-crushing Machinery and Processes of Ore Treatment." By Mr. A. G. Charleton.

"The Ordnance Maps: the Defects and their Remedies." By Mr. Henry T. Crook.

"Some Systems of Underground Haulage at Messrs. Charlesworth's Collieries." By Mr. Walter Hargreaves.

"Rapid Traverser." By Mr. James Henderson.

"A New Method of Laying Coal-dust." By Mr. H. Richardson Hewitt.

"Notes upon a Practical Method of Ascertaining the Value or Price to be Paid for Zinc Mineral." By Mr. H. D. Hoskold.

"The Education of Mining Engineers." By Prof. J. H. Merivale.

"Electric Lighting and Transmission of Power." By Mr. W. M. Mordey.

"Description of Mining Relics found at the Heath End Colliery." By Mr. W. B. Scott.

"Compressed Oxygen." By Prof. R. H. Smith.

The foregoing lists demonstrate the varied nature of the papers communicated during the year, several being upon subjects of importance, as evidenced by the lengthy and valuable discussions thereon.

The translation of the "Report of the Prussian Fire-damp Commission," which is concluded in the *Transactions* of this year, should also prove of service to members.

The Council have awarded prizes to the authors of the following papers, which are printed in volume iii. of the *Transactions*:—

PRESIDENT'S PRIZE.

"Mining in New Zealand." By Mr. G. J. Binns.

INSTITUTION PRIZES.

"A General Description of the South Staffordshire Coal-field, south of the Bentley Fault, and the Methods of Working the Ten-yard or Thick Coal." By Messrs. W. F. Clark and H. W. Hughes.

"Observations on Petroleum in Eastern Europe, and the Method of Drilling for it." By Mr. A. W. Eastlake.

"An Enquiry into the Cause of the two Seaham Explosions, 1871 and 1880, and the Pochin Explosion, 1884." By Mr. T. H. M. Stratton.

The "Notes of Papers on the Working of Mines, Metallurgy, etc., from the Transactions of Foreign Societies and Foreign Publications" have been continued, and should prove of value to the members.

The papers having become so numerous necessitated the *Transactions* being printed in two volumes, and it is trusted that these will be received with satisfaction by the members.

LIST OF BOOKS, ETC., ADDED TO THE LIBRARY.

Colliery Engineer, vol. xiii., Nos. 4-11.

Collins, J. H., Seven Centuries of Tin Production in the West of England.

Cory Brothers & Co., Ltd., British Coal Trade and Freight Circular for the Months ending Oct. 31st, Nov. 30th, and Dec. 31st, 1892; Jan. 31st., Feb. 28th, Mar. 31st, April 30th, May 31st, June 30th, and July 31st, 1893.

Engineering and Mining Journal, vol. liv., Nos. 2, 3, 5-13, 15-27; vol. lv., Nos. 1-25; vol. lvi., Nos. 1-7.

Handbook of the Mozambique Company, Province of Manica-Sofala, 1893.

Illinois Mining Institute, Journal, vol. i., 1892-93.

Institute of Chemistry of Great Britain and Ireland, Register of Fellows, Associates, and Students, 1883-84.

Mines, 1892, Summaries of the Statistical portion of the Reports of H.M. Inspectors of Mines.

Mining Society of Nova Scotia, Transactions, vol. i.

Noble, John, Illustrated Handbook of the Cape and South Africa, 1893.

Report of the British Association Meeting held at Edinburgh, 1892.

Reference Map of the United States, 1893.

Report of the Departmental Committee appointed by the Board of Agriculture to enquire into the present Condition of the Ordnance Survey, 1893.

Report on the Risks arising and the Precautions to be adopted in the Manufacture and Handling of Nitro-Benzole and Di-Nitro-Benzole. By Dr. Dupré and Commander Hamilton P. Smith, R.N.

Spargo, Edmund, Familiar Faces, 1891.

Smith, Hamilton, The Witwatersrand Gold-fields, 1893.

South African Mining Investors' Agency Special Mining Circular, Jan. 28th, Feb. 18th, and April 15th, 1893; issued by the South African Trust and Finance Co., Ltd.

Wilson, John Veitch, Paper on Lubrication.

Woodward, Harry Page, Western Australia, Annual General Report for the Year 1890; Report on the Gold-fields of the Kimberley District, 1891; Catalogue of Exhibits at the International Exhibition of Mining and Metallurgy, London, 1890, with an Appendix containing an Account of the principal Mining Districts of the Colony.

THE LOCAL INSTITUTES IN ACCOUNT WITH THE FEDERATED INSTITUTION OF MINING ENGINEERS, FOR THE YEAR ENDING JULY 31ST, 1898.

Dr.

	No. of Members.	Balance due at the beginning of the year.	Amounts falling Due during the Year. Calls made during the year.	Excerpts.	Transactions: Reducing Plates, etc.	Total.
		£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Chesterfield and Midland Counties Institution of Engineers ...	289	12 0 0	255 3 0	12 18 9	11 5 0	291 6 9
Midland Institute of Mining, Civil, and Mechanical Engineers	189	0 15 0	169 16 0	9 15 6	3 16 0	184 2 6
North of England Institute of Mining and Mechanical Engineers	740	27 0 0	658 4 0	83 16 10	29 5 0	798 5 10
North Staffordshire Institute of Mining and Mechanical Engineers	203	63 5 5	168 14 0	7 13 6	1 1 0	240 13 11
South Staffordshire and East Worcestershire Institute of Mining Engineers...	98	78 12 5	85 15 0	3 0 3	5 7 6	172 15 2
	1,519	181 12 10	1,337 12 0	117 4 10	50 14 6	1,687 4 2

Cr.

	Amounts Paid during the Year. Balance from previous year.	Calls.	Excerpts.	Transactions: Reducing Plates, etc.	Total.	Balance due at July 31st, 1898.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Chesterfield and Midland Counties Institution of Engineers ...	12 0 0	255 3 0	12 18 9	11 5 0	291 6 9	...
Midland Institute of Mining, Civil, and Mechanical Engineers	0 15 0	169 16 0	9 15 6	3 16 0	184 2 6	...
North of England Institute of Mining and Mechanical Engineers	27 0 0	658 4 0	83 16 10	29 5 0	798 5 10	...
North Staffordshire Institute of Mining and Mechanical Engineers	63 5 5	106 15 0	...	...	170 0 5	70 13 6
South Staffordshire and East Worcestershire Institute of Mining Engineers	78 12 5	69 15 0	...	...	148 7 5	24 7 9
	181 12 10	1,259 13 0	106 11 1	44 6 0	1,592 2 11	95 1 3

Dr. THE TREASURER IN ACCOUNT WITH THE
FOR THE YEAR

		£ s. d.	£ s. d.
To Balance at Bank		575 10 9	
" " in Treasurer's hands		35 0 10	610 11 7
To Subscriptions for year ending July 31, 1891—			
Federated—			
South Staffordshire and East Worcestershire Institute of Mining Engineers			2 2 5
To Subscriptions for year ending July 31, 1892—			
Federated—			
Chesterfield and Midland Counties Institution of Engineers		12 0 0	
Midland Institute of Mining, Civil, and Mechanical Engineers		0 15 0	
North of England Institute of Mining and Mechanical Engineers		27 0 0	
North Staffordshire Institute of Mining and Mechanical Engineers		63 5 5	
South Staffordshire and East Worcestershire Institute of Mining Engineers	£78 0 0		
Allowance	1 10 0		
		76 10 0	179 10 5
To Subscriptions for year ending July 31, 1893—			
Federated—			
Chesterfield and Midland Counties Institution of Engineers	£216 15 0		
Midland Institute of Mining, Civil, and Mechanical Engineers	141 15 0		
North of England Institute of Mining and Mechanical Engineers	555 0 0		
North Staffordshire Institute of Mining and Mechanical Engineers	100 5 0		
South Staffordshire and East Worcestershire Institute of Mining Engineers	69 15 0		
		1,083 10 0	
Non-Federated—			
Midland Institute of Mining, Civil, and Mechanical Engineers	£3 0 0		
North Staffordshire Institute of Mining and Mechanical Engineers	6 10 0		
		9 10 0	1,093 0 0
Carried forward			£1,885 4 5

Federated Institution of Mining Engineers. **Cr.**

ending July 31, 1893.

	£	s.	d.	£	s.	d.	£	s.	d.
By Printing—									
Transactions, Vol. I., printing	62	19	0						
" " I., plates	40	19	0						
				103	18	0			
" " II., printing	44	16	0						
" " II., plates	25	18	6						
				70	14	6			
" " III., printing	421	18	4						
" " III., plates	236	2	5						
				658	0	9			
" " IV., printing	294	1	3						
" " IV., plates	126	14	1						
				420	15	4			
Excerpts, Vol. I.	11	5	8						
" " II.	5	7	10						
" " III.	87	2	0						
" " IV.	65	16	10						
				169	12	4			
Galley Proofs for Revision				2	7	8			
Circulars				21	13	9			
Proofs of Papers for General Meetings				15	13	6			
Advertizements				2	3	6			
							1,464	19	4
" Stationery, etc.	37	6	9						
Less Discount	0	3	9						
				37	3	0			
" Postages—Transactions	131	7	5						
" " Circulars	6	1	1						
" " Office	28	2	11						
				165	11	5			
" Addressing Transactions	12	10	0						
" " Circulars	2	5	0						
				14	15	0			
" Insurance of Transactions				1	4	2			
" Binding, Transactions	46	8	0						
" " Sundries	3	0	0						
				49	8	0			
Carried forward				£268	1	7	£1,464	19	4

Dr. THE TREASURER IN ACCOUNT WITH THE

	£	s.	d.	£	s.	d.
Brought forward				1,885	4	5
To Special Call—						
Chesterfield and Midland Counties Institution of Engineers	38	8	0			
Midland Institute of Mining, Civil, and Mechanical Engineers	25	1	0			
North of England Institute of Mining and Mechanical Engineers	103	4	0			
				166	13	0
To Local Publications and Authors' Copies—						
Chesterfield and Midland Counties Institution of Engineers	12	18	9			
Midland Institute of Mining, Civil, and Mechanical Engineers	9	15	6			
North of England Institute of Mining and Mechanical Engineers	83	16	10			
Federated Institution of Mining Engineers	40	6	9			
				146	17	10
To Sales of Transactions—						
Chesterfield and Midland Counties Institution of Engineers	9	15	0			
Midland Institute of Mining, Civil, and Mechanical Engineers	0	6	0			
North of England Institute of Mining and Mechanical Engineers	17	5	0			
Members, etc.	100	1	6			
				127	7	6
To Reducing Plates—						
Chesterfield and Midland Counties Institution of Engineers	1	10	0			
Midland Institute of Mining, Civil, and Mechanical Engineers	3	10	0			
North of England Institute of Mining and Mechanical Engineers	12	0	0			
				17	0	0
Advertizements				165	15	6
				£2,508	18	3

FEDERATED INSTITUTION OF MINING ENGINEERS.—*Continued.* Cr.

	£ s. d.	£ s. d.	£ s. d.
Brought forward		268 1 7	1,464 19 4
By Expenses of Meetings—Reporting		26 14 0	
„ Incidental Expenses		13 3 1	
„ Salaries, Wages, etc.—			
Accountant (2 years)	2 2 0		
Clerks	120 16 8		
Secretary (13 months)	216 13 4		
Stock-keeper (2 years)	8 0 0		
Treasurer (16 months)	28 0 0		
		375 12 0	
„ Indexing Transactions (3 years)		13 0 0	
„ Travelling Expenses—Secretary	33 17 9		
„ „ „ Treasurer	9 12 0		
		43 9 9	
			740 0 5
„ Commission on Advertizements			57 9 6
„ Prizes, Vol. III.			25 0 0
„ Translations of Papers		28 10 0	
„ Abstracts of Foreign Papers		47 10 0	
			76 0 0
„ Balance at Bank		125 1 11	
„ „ in Treasurer's hands		20 7 1	
			145 9 0
			£2,508 18 3

Liabilities.

	£	s.	d.	£	s.	d.	£	s.	d.
Sundry Creditors—									
Printing, etc.	450	0	0						
Postage of Transactions	75	0	0						
Abstracts of Foreign Papers	60	0	0						
Prizes, Vol. IV.	15	0	0						
Commission on Advertizements	26	19	11						
				626	19	11			
Advertizements Paid in Advance				11	15	0			
							638	14	11
Balance of Assets over Liabilities							208	9	5
							£847	4	4

I have examined the above Balance Sheet with the books and vouchers relating thereto, and certify that in my opinion it exhibits a correct view of the affairs of the Institution.

JOHN G. BENSON, Chartered Accountant.

Newcastle-upon-Tyne, August 28th, 1893.

ENGINEERS.—GENERAL STATEMENT, JULY 31, 1893.

Assets.

	£ s. d.	£ s. d.
Balance at Bank, etc.	125 1 11	
„ in Treasurer's hands	20 7 1	
		145 9 0
Subscriptions Unpaid, Year ending July 31, 1893—		
Federated—		
North Staffordshire Institute of Mining and Mechanical Engineers	52 0 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	3 15 0	
		55 15 0
Special Call Unpaid—		
North Staffordshire Institute of Mining and Mechanical Engineers	9 19 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	12 5 0	
		22 4 0
Excerpts Unpaid—		
North Staffordshire Institute of Mining and Mechanical Engineers	7 13 6	
South Staffordshire and East Worcestershire Institute of Mining Engineers	3 0 3	
Members, etc.	0 16 11	
		11 10 8
Transactions Sold—		
North Staffordshire Institute of Mining and Mechanical Engineers	1 1 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	5 7 6	
Members, etc.	0 15 0	
		7 3 6
Advertizements to July 31st, 1893, outstanding		177 19 2
		420 1 4
Transactions—		
5 Volumes at 13s. 6d.	3 7 6	
12 „ 10s. 6d.	6 6 0	
6 „ 10s. 3d.	3 1 6	
6 „ 8s. 6d.	2 11 0	
778 „ 7s.	272 6 0	
2,791 Parts at 1s.	139 11 0	
1,713 Copies, Excerpts of Papers, etc.	Nil.	
		427 3 0
		£847 4 4

ELECTION OF OFFICERS.

The SECRETARY announced the following elections by the Council:—

PRESIDENT.—Mr. ARTHUR SOPWITH.

VICE-PRESIDENTS.

Mr. WM. ARMSTRONG, Jun.	Mr. W. E. GARFORTH.
Mr. J. B. ATKINSON.	Mr. WM. HEATH.
Mr. ALFRED BARNES.	Mr. HENRY LEWIS.
Mr. W. F. CLARK.	Mr. RALPH MOORE.
Mr. WILLIAM COCHRANE.	Mr. J. B. SIMPSON.
Mr. R. H. COLE.	Mr. A. L. STEAVENSON.

TREASURER.—Mr. REGINALD GUTHRIE.

AUDITOR.—Mr. JOHN GEORGE BENSON.

The CHAIRMAN remarked that it now only remained for him to ask Mr. A. Sopwith to take the chair. He was exceedingly pleased to know that so able a gentleman was to succeed him in the chair, and he hoped his year of office would see the same substantial advance, and that he would have the same assistance from the members of Council, as he had had. The work of an institution of this kind was very considerable, and, but for the help of the Council and the Secretary, he was afraid that the President would find it a very difficult and arduous matter. The Secretary (Mr. M. Walton Brown) had saved him every possible labour and trouble, and he thought the least he could do was to thank him for his able and kind assistance.

Mr. ARTHUR SOPWITH then took the chair and expressed his thanks for the great honour that had been done to him in electing him President of the Federated Institution of Mining Engineers, an Institution which was now assuming very large proportions. He could only say that he hoped his year of office would be as successful as that of his predecessor, and that, at all events, the Institution would be indebted to him for some work that he could do in connexion with it, as it had benefited by the services of Mr. Lewis. He could endorse what Mr. Lewis had said as to this being rather an auspicious occasion. Their membership had been very considerably increased, and he thought the Federated Institution of Mining Engineers should congratulate itself upon the accession of the Mining Institute of Scotland, and he thought also, that the members of the Mining Institute of Scotland might also congratulate themselves that they had made up their minds to join the Federated Institution of Mining Engineers. Before he sat down he would ask them to give a cordial vote of thanks to Mr. Lewis for his services during the past year as their President, and for the way in which he had managed their business, he most especially deserved their hearty thanks.

Mr. J. B. ATKINSON (Glasgow) had much pleasure in seconding the motion. As the Mining Institute of Scotland had only joined the Federated Institution of Mining Engineers at that meeting, he had not personally had the advantage of meeting Mr. Lewis in his capacity of President; but, from his knowledge of the work that was required from himself as President of the Mining Institute of Scotland, he could well conceive what an arduous task Mr. Lewis had had, and that for conducting the affairs of an Institution like the Federated Institution of Mining Engineers so successfully, he deserved their hearty thanks.

The motion was cordially approved by the members.

Mr. LEWIS, in reply, thanked the members warmly for their hearty vote of thanks. He could only say, if he had been useful to the Institution or if it had been successful during his year of office, it had been more especially owing to the exertions of the Council and of the Secretary (Mr. M. Walton Brown) than to himself. He had felt it a great honour during the year to be President of the Federated Institution of Mining Engineers, and he was sure that in the future, they would be looked upon very differently from now. As they were aware, they started with a much smaller number of members than at present, but during the past three years the membership had rapidly increased. He thought one of the great advantages of the Institution was that they met in different parts of the country, and although they might be looked upon as a purely scientific body, he thought it was an important element that they should see the collieries in the various districts. He was very much obliged to them for their vote of thanks.

Mr. W. F. HOWARD read the following paper, by Mr. Walcot Gibson, on the "Geology of the Southern Transvaal":—

GEOLOGY OF THE SOUTHERN TRANSVAAL.

By WALCOT GIBSON.

The importance of the Transvaal gold-fields is now fully established. Over 1,200,000 ounces of gold were obtained last year from the Witwatersrand alone. The main reef has been proved in several deep levels, and the pyritic ores have been very successfully treated. With coal close at hand, and with rapidly increasing railway communication, the value of these gold-fields cannot be questioned. An account of the geological structure of the country may not be out of place, since it clearly shows that the value of the Transvaal as a mineral-producing country is not overestimated.

The Southern Transvaal forms a portion of the high veld of South Africa. Igneous rocks, in the form of intrusive sheets, dykes, and necks, cover extensive tracts. The coal-bearing strata come next in importance as regards the area occupied by them, while from beneath the igneous rocks and coal-measure sandstones, auriferous conglomerates crop out in several localities.

North of Johannesburg, an extensive tract is composed of metamorphic rocks, consisting of gneiss and granite with several varieties of altered igneous rocks, chiefly basic in character—gabbros, basalts, etc. These belong to the oldest formations in the Transvaal. They were much denuded before any strata were deposited on them, and they undoubtedly formed the solid unyielding mass against and over which the gold-bearing strata were thrust.

Few exposures are met with near Johannesburg, since the rocks form gently rolling grass-covered country and seldom rise into hills. They can best be seen on the Houghton estate, where they consist largely of micaceous acid gneisses, crossed by quartz-veins and pierced by graphic granite, remarkable for the relatively large size of the quartz and felspar-crystals. The remainder consists of quartzites and highly contorted hornblende and mica-schists ; chlorite-schists are not uncommon. Talc and asbestos are abundantly developed, but the fibre of the asbestos is very short.

In some geological sections these metamorphic rocks are represented as granites of newer date than the auriferous conglomerates, which are stated to owe their inclination to the upheaval of the granite. This is certainly not the case, for they are far older than the conglomerates, and so far from being upheaved, constitute the solid rock against which the conglomerate series is thrust.

The next oldest rocks consist of quartzites, shales, and conglomerates. They call for special attention, as it is in some of the conglomerate-bands that the gold is found. For convenience of description, the entire series of quartzites, shales, and conglomerates will be called the "banket formation" in this paper, and the bands of "banket" or conglomerate forming the north reef, main reef, and south reef, will be grouped together as the main reef.

The banket formation is well developed in the neighbourhood of Johannesburg, where numerous exposures and mines give excellent sections. What appear to be the lowest beds consist of quartzite and quartz-rock, succeeded by red-and-black hardened shales. The quartzites form the high ground north of Johannesburg, the valleys being excavated in shales. The lowest bed consists of nearly pure quartz-rock about 150 feet thick. In a drift into the base of this bed on the Houghton estate, it is clearly seen that the quartz-rock is an altered sediment which has been thrust over the metamorphic rocks. A narrow conglomerate-band, still recognizable as such, proves this conclusively. The pebbles are seen to be elongated in one direction; and the original matrix flows round the pebbles, forming a rock resembling an augen-gneiss.

The quartz-rock is overlain by intensely hardened shales. On the road leading from Johannesburg to the Houghton mine, and near the gap in the ridge formed out of the quartz-rock, the shales are caught up and twisted between bands of quartzite.

Overlying the shales are three beds of quartzite, the two lowest being overlain by red-and-black shales. The average dip of the quartzites is 55 degs. south, but the shales generally have a higher dip. Looking at these quartzite ridges from the high ground behind Johannesburg, the conclusion seems inevitable that they are one band repeated by overfaulting. The beds of shale and quartzite are identical in thickness and composition, while the wedge-shaped nature of the bands of quartzite is most distinct.

Direct evidence that these beds are folded and overthrust is afforded by the shales. Behind the Landrost's house, close to the road leading to Auckland Park, the shales are seen to be folded, and a large block shows

crumplings and twisting and minor thrust-planes as distinct as those in an Alpine schist. There can be no doubt that at this particular spot some powerful force has acted, strong enough to fold the shales. That this is not a mere local phenomenon, but is due to a general movement affecting the whole series, becomes evident as the shales are traced along the strike. By walking eastwards along the outcrop of the shales the dip is plainly seen to have passed the normal, so that the southerly dip is only an apparent one.

To the west of Johannesburg, the quartzite-bands extend as far as Krugersdorp, but to the east they end off one after another, against a powerful thrust-fault running up the Doornfontein valley. This fault separates the quartzites and shales from the main reef series. If there be no fault here, the main reef must be unconformable to the quartzites and shales, for while behind Johannesburg the quartzites dip at 45 degs., the main reef is nearly vertical. But an unconformity is not admissible, since the strike of the main reef remains constantly parallel to that of the quartzites.

Resting on the quartzites and shales, but with a faulted junction, as just shown, is an apparently vast thickness of sandstones and conglomerates, towards the base of which two or more bands of conglomerate occur, constituting the famous main reef, the richest and most constant gold-bearing zone of the Witwatersrand. These measures occupy the ground between Johannesburg and the Eagle's Nest, and extend from Boksburg to Krugersdorp. On the northern outcrop the beds have a high dip (85 degs. to 60 degs.) near Johannesburg. They appear to flatten out gradually to the south till they come to lie at an angle of 15 degs. This flattening out southwards has led all who have written on the subject to consider the beds as lying in a simple unbroken syncline, and if the faulted relation of the strata to the underlying quartzites and shales be not recognized, and if attention be only paid to surface outcrops, such a conclusion is inevitable. A careful examination of the strata, more particularly those composing the main reef, reveals abundant proof that great pressure has been exerted, and that under its influence the beds have in many instances given way, and thus disturbed the synclinal arrangement.

The main reef is composed of four beds of conglomerate, each averaging 4 feet in thickness. They are distinguished as north reef, main reef, with its leader, and south reef. This distinction of four reefs refers only to their relative position, for little mineralogical difference can be detected other than of quite local application. All four reefs consist of a

conglomerate composed almost exclusively of pebbles of white quartz and quartzite. The south reef is generally considered to contain a greater percentage of pebbles of black quartz, but this distinguishing feature can only be applied to one or two mines. Whatever difference there is, it is so slight as to be practically inappreciable. The south reef, as a rule, carries the most gold, but there are exceptions.

It is important to notice that, traced in depth, the loose, surface-red conglomerate becomes a hard, blue, compact rock, crowded with crystals of iron pyrites, while the same change affects the country rock, which from being a soft red sandstone at the surface becomes converted on the lower levels into a compact quartzite or a hard micaceous schistose rock, containing numerous crystals of iron pyrites.

The foot-walls and hanging-walls present smooth surfaces, and the division between the coarse conglomerates and the fine-grained country rock is clear and sharp, and devoid of irregularities.

A microscopical examination of the pyritic conglomerate from the Robinson mine reveals the following interesting structures. In ordinary transmitted light numerous lines of strain are observed to pass across both pebbles and matrix, showing that the rock has been subjected to pressure subsequent to consolidation. Lines of bubbles are developed in the quartz-pebbles and matrix. The iron pyrites is seen to be of secondary origin. Polarized light shows that what look like two separate pebbles are really one pebble broken asunder, secondary quartz being developed between them. It is not uncommon to find that two pebbles lying near to each other are in optical continuity. Many of the pebbles are very much broken, displaying under the microscope a mosaic of colours.

Microscopic examination thus shows that the strata have been subjected to great pressure, and fully confirms the results obtained from a stratigraphical investigation. The pressure has evidently been sufficient to break and crush the pebbles and to develop lines of strain, but it was not intense enough to roll the pebbles out in the direction of movement. The result of the pressure has certainly been to make a compact rock out of an original incoherent conglomerate.

It now remains to show how far the beds in mass have been affected by the movements.

In the mines near Johannesburg, there is little evidence of faulting, but since the dip of the beds is high, and the faults are chiefly of a reverse kind, the horizontal displacement of a really powerful fault is not great and affects the miner very little. Still, faults are more numerous than is supposed, for since they do not interfere with mining, they are

not noticed, but the accumulated effect of numerous very small overfaults must be great. It is in this way that the beds have accommodated themselves to the smaller space they were compelled to occupy. The beds of conglomerate and sandstone could not fold like the shales, but as they became more and more compact under pressure, the individual beds snapped and rode over each other. The result of the overfaulting is to bring the beds closer together, at the same time carrying them nearer the surface.

Besides causing the beds to become closely packed, pressure has effected another change in the original condition of the conglomerates and sandstones. In a hand-specimen of the banket, one of the most characteristic features is the coating of each pebble with a thin film of talc. There is little doubt that this mineral is manufactured by slow and continuous pressure out of the original felspathic material of the matrix.

The sandstones have been affected in the same way. The sand-grains have been partially rounded till the rock was converted into a quartzite, and where the pressure was great enough, a large quantity of silica segregated out in the form of quartz-veins. The felspathic material was converted into a talcose mineral, which arranged itself in layers at right angles to the direction of pressure, giving the rock a schistose structure.

Further evidences of the strata having been intensely squeezed is given by the 200 feet level of the Henry Nourse mine and by the disposition of the strata forming Jeppes hill. In the cross-cut north, on the 200 feet level of the Henry Nourse mine, five wedge-shaped reefs have been cut through. They are veined with quartz and intensely hard. The country rock consists of quartzite and chlorite-schists, the latter being much crumpled and puckered up. In Jeppes hill the evidence of thrusting is still stronger. In a transverse gully leading from the Doornfontein valley to the summit of the hill the schistose nature of the beds and their wedge-shaped arrangement are most clearly demonstrated. The strata consist of quartzites, mica-schists, and several bands of conglomerate. The upper part of the series is conglomeratic and is overlain by shales and quartzites, identical with those previously described as lying beneath the main reef north of Johannesburg. This apparent reversal of the sequence is plainly due to overfaulting. The position of the fault is marked by a 2 feet band of white quartz.

Evidences of thrusting can be obtained in any mine along the northern outcrop, if the beds are carefully examined. The country rock in all cases is either a quartzite or schistose rock, and the strata are frequently broken through by small overfaults.

It would be superfluous to bring forward further evidences that the strata have been thrusted.

An examination of the main reef, as developed in the mines east and west of Johannesburg, shows that the conglomerate-bands form lenticles in the encasing rock. Thus, in the Salisbury mine, the main reef and its leader are 24 feet apart. In the Robinson mine they have come together, and farther west they cannot be recognized as separate bands. Traced still farther westward in the Durban Roodepart and Princess mines, the reefs have thinned out, the south reef being represented in places by a thin line of pebbles.

East of the Jumpers mine, and again west of the Princess mine, the distinction into main and south reef vanishes. Other reefs of similar lithological character to parts of the main reef (but never so rich in gold) take their place or represent them.

At Krugersdorp and Boksburg, the westerly and easterly extremities of the outcrop of the main reef, the beds assume a southerly strike, but they are soon cut off by broad dykes of basic igneous rocks.

South of Johannesburg the dip of the main reef series gradually decreases to the Klip River Spruit. The Klipriversberg Gold Mining Company, judging from the slickensided material thrown out on the surface, seem to have sunk down on a fault, and there is evidence that this fault is continued along the Klip River Spruit. South of this fault auriferous conglomerates crop out, having a constant dip of 15 degs. To what part of the series these conglomerates belong, it is impossible to decide. They may lie above or below the main reef, but it is certain that the main reef continues up to the fault. From the northern outcrop to this fault is a distance of nearly three miles. This distance represents the breadth of the band upon which the main reef will be found to exist at workable depths. The depth at which the reef will be struck will always be uncertain. In some cases overfaulting will bring the beds comparatively close to the surface, and in all cases the reef will be struck at a shallower depth than one calculated by the dip on the northerly outcrop.

South of the great igneous outflows of the Eagle's Nest, the banket formation crops out to form the black reef, but the author only crossed the reefs once and had no opportunity of examining them.

Conglomerates, sometimes auriferous, but evidently belonging to the same formation as the Witwatersrand conglomerates, are found outside the Witwatersrand. The most important is the conglomerate forming the Nigel reef in the Heidelberg district. It is impossible to correlate this

reef with any on the Witwatersrand. The foot-wall consists of shale about 50 feet thick. Both conglomerate and shale become pyritic in depth, and the reef seems to be a local development.

The surrounding country is covered by igneous rock which conceals much of the strata. West of the town of Heidelberg conglomeratic sandstones crop out in several places, but although they are surrounded by igneous rocks they are not auriferous. This is only one of many other instances where proximity to igneous rocks is not accompanied by the presence of gold.

The occurrence of auriferous conglomerates and quartzites near the Vaal river, on the Strykfontein farm, and again in the hilly region west of Vredefort, is interesting as serving to connect the banket formation of the Heidelberg district with the gold-bearing conglomerates of Potchefstroom and Klerksdorp.

West of Vredefort, the strata are thrown into sharp anticlines and synclines, the axes of which run north and south. The lowest beds appear to be quartzites and shales, which dip at a very high angle off the metamorphic rocks outcropping round the town of Vredefort. The conglomerates which succeed the quartzites and shales are similar in character to those of the Witwatersrand, but they are not rich in gold, though pierced and covered by basic igneous rocks.

The conglomerates exposed in the hills near Lindequisfontein on the Vaal river, plunge to the west beneath igneous rocks, and are not met with again till about twenty miles west of Potchefstroom, where they are worked for gold on the Buffelsdoorn estate.

In the Klerksdorp district, the beds are also thrown into folds whose axes trend north and south. The conglomerates are chiefly composed of quartz-pebbles and quartzites, but some of the beds are much thicker than those on the Witwatersrand. They have not as yet proved themselves so rich in gold as the main reef. Igneous rocks conceal most of the outcrops.

Isolated patches of conglomerate occur west of Cronstadt on the farms of Damspruit and Veld-de-freden. The strata are folded, but there are few exposures. The conglomerates are poor in gold.

The banket beds outside the Witwatersrand area are thus seen to be thrown into folds which become shallower towards the south. This shows that the maximum yielding of the beds took place on the northern outcrop near Johannesburg. The strata were here prevented from folding by the presence of the underlying unyielding metamorphic rocks.

The interval in time that elapsed between the folding and tilting of the banket beds and the deposition on their upturned edges of sandstone

and coal was marked by vast outflows of igneous rock. At least the evidence so far tends to show that the outpouring and intrusion of the lavas was anterior to the deposition of the coal-bearing sandstones, for the latter show no signs of alteration where in close proximity to igneous masses.

The relation of the coal-bearing beds to the conglomerates is one of complete unconformity, which is very clearly seen in the Cinderella mine, near Boksburg, where horizontal coal-measure sandstones rest on banket beds dipping at 45 degs.

The sandstones appear to be of lacustrine origin, and the coal is of drift formation.

The geological age of the metamorphic rocks, banket, and coal-bearing sandstones has not yet been determined. The coal-measures are probably of Upper Karoo age, and the metamorphic rocks are possibly of the same age as the Namaqualand schists. The igneous rocks are certainly intrusive into the banket beds, and are apparently anterior in date to the formation of the coal.

Since the base and summit of the banket series is not known, and since even the sequence of the beds is uncertain, it is impossible to estimate the geological age of the gold-bearing conglomerates. Until fossils are discovered, and the strata are met with in areas where they have not been metamorphosed, and where the summit or base is seen, it is better to leave the age and origin of the banket formation an open question. It is useless to advance theories based entirely on negative evidence, and from a mining point of view it is unimportant what the age or origin may be, while science demands that theory should be based on fact.

THE ORIGIN OF THE GOLD.

In attempting to solve the question of the origin of the gold in the banket conglomerate it is necessary to bear in mind all the facts of the case, stratigraphical and mineralogical. Briefly stated they are these :—

(1) There is an apparently great thickness of quartzites, mica-schists, and talc-schists with numerous intercalated lenticular bands of crusted conglomerates, the pebbles of which consist almost exclusively of quartz and quartzite. These beds can be traced along the strike for a distance of 45 miles, and as many more on the dip. The beds are pierced by basic igneous rocks and surrounded by rocks of the same character. They are literally floating in igneous rocks. The intrusion and outpouring of these igneous rocks were posterior to the crushing and thrusting of the strata.

Dr. THE TREASURER IN ACCOUNT WITH THE
FOR THE YEAR

		£ s. d.	£ s. d.	£ s. d.
To Balance at Bank			575 10 9	
" " in Treasurer's hands			35 0 10	
				610 11 7
To Subscriptions for year ending July 31, 1891—				
Federated—				
South Staffordshire and East Worcestershire Institute of Mining Engineers				2 2 5
To Subscriptions for year ending July 31, 1892—				
Federated—				
Chesterfield and Midland Counties Institution of Engineers			12 0 0	
Midland Institute of Mining, Civil, and Mechanical Engineers			0 15 0	
North of England Institute of Mining and Mechanical Engineers			27 0 0	
North Staffordshire Institute of Mining and Mechanical Engineers			63 5 5	
South Staffordshire and East Worcestershire Institute of Mining Engineers	£78 0 0			
Allowance	1 10 0			
			76 10 0	
				179 10 5
To Subscriptions for year ending July 31, 1893—				
Federated—				
Chesterfield and Midland Counties Institution of Engineers	£216 15 0			
Midland Institute of Mining, Civil, and Mechanical Engineers	141 15 0			
North of England Institute of Mining and Mechanical Engineers	555 0 0			
North Staffordshire Institute of Mining and Mechanical Engineers	100 5 0			
South Staffordshire and East Worcestershire Institute of Mining Engineers	69 15 0			
			1,083 10 0	
Non-Federated—				
Midland Institute of Mining, Civil, and Mechanical Engineers	£3 0 0			
North Staffordshire Institute of Mining and Mechanical Engineers	6 10 0			
			9 10 0	
				1,093 0 0
Carried forward				£1,885 4 5

FEDERATED INSTITUTION OF MINING ENGINEERS. Cr.
ENDING JULY 31, 1893.

	£ s. d.	£ s. d.	£ s. d.
By Printing—			
Transactions, Vol. I., printing	62 19 0		
" " I., plates	40 19 0		
		103 18 0	
" " II., printing	44 16 0		
" " II., plates	25 18 6		
		70 14 6	
" " III., printing	421 18 4		
" " III., plates	236 2 5		
		658 0 9	
" " IV., printing	294 1 3		
" " IV., plates	126 14 1		
		420 15 4	
Excerpts, Vol. I.	11 5 8		
" " II.	5 7 10		
" " III.	87 2 0		
" " IV.	65 16 10		
		169 12 4	
Galley Proofs for Revision		2 7 8	
Circulars		21 13 9	
Proofs of Papers for General Meetings		15 13 6	
Advertizements		2 3 6	
			1,464 19 4
" Stationery, etc.	37 6 9		
Less Discount	0 3 9		
		37 3 0	
" Postages—Transactions	131 7 5		
" " Circulars	6 1 1		
" " Office	28 2 11		
		165 11 5	
" Addressing Transactions	12 10 0		
" " Circulars	2 5 0		
		14 15 0	
" Insurance of Transactions		1 4 2	
" Binding, Transactions	46 8 0		
" " Sundries	3 0 0		
		49 8 0	
Carried forward		£268 1 7	£1,464 19 4

Dr. THE TREASURER IN ACCOUNT WITH THE

	£	s.	d.	£	s.	d.
Brought forward				1,885	4	5
To Special Call—						
Chesterfield and Midland Counties Institution of Engineers	38	8	0			
Midland Institute of Mining, Civil, and Mechanical Engineers	25	1	0			
North of England Institute of Mining and Mechanical Engineers	103	4	0			
				166	13	0
To Local Publications and Authors' Copies—						
Chesterfield and Midland Counties Institution of Engineers	12	18	9			
Midland Institute of Mining, Civil, and Mechanical Engineers	9	15	6			
North of England Institute of Mining and Mechanical Engineers	83	16	10			
Federated Institution of Mining Engineers	40	6	9			
				146	17	10
To Sales of Transactions—						
Chesterfield and Midland Counties Institution of Engineers	9	15	0			
Midland Institute of Mining, Civil, and Mechanical Engineers	0	6	0			
North of England Institute of Mining and Mechanical Engineers	17	5	0			
Members, etc.	100	1	6			
				127	7	6
To Reducing Plates—						
Chesterfield and Midland Counties Institution of Engineers	1	10	0			
Midland Institute of Mining, Civil, and Mechanical Engineers	3	10	0			
North of England Institute of Mining and Mechanical Engineers	12	0	0			
				17	0	0
Advertizements				165	15	6
				£2,508	18	3

FEDERATED INSTITUTION OF MINING ENGINEERS.—*Continued.* **Cr.**

	£	s.	d.	£	s.	d.	£	s.	d.
Brought forward				268	1	7	1,464	19	4
By Expenses of Meetings—Reporting				26	14	0			
„ Incidental Expenses				13	3	1			
„ Salaries, Wages, etc.—									
Accountant (2 years)	2	2	0						
Clerks	120	16	8						
Secretary (13 months)	216	13	4						
Stock-keeper (2 years)	8	0	0						
Treasurer (16 months)	28	0	0						
				375	12	0			
„ Indexing Transactions (3 years)				13	0	0			
„ Travelling Expenses—Secretary	33	17	9						
„ „ „ Treasurer	9	12	0						
				43	9	9			
							740	0	5
„ Commission on Advertizements							57	9	6
„ Prizes, Vol. III.							25	0	0
„ Translations of Papers				28	10	0			
„ Abstracts of Foreign Papers				47	10	0			
							76	0	0
„ Balance at Bank				125	1	11			
„ „ in Treasurer's hands				20	7	1			
							145	9	0
							£2,508	18	3

Liabilities.

	£ s. d.	£ s. d.	£ s. d.
Sundry Creditors—			
Printing, etc.	450 0 0		
Postage of Transactions	75 0 0		
Abstracts of Foreign Papers	60 0 0		
Prizes, Vol. IV.	15 0 0		
Commission on Advertizements	26 19 11		
		626 19 11	
Advertizements Paid in Advance		11 15 0	
			638 14 11
Balance of Assets over Liabilities			208 9 5
			£847 4 4

I have examined the above Balance Sheet with the books and vouchers relating thereto, and certify that in my opinion it exhibits a correct view of the affairs of the Institution.

JOHN G. BENSON, Chartered Accountant.

Newcastle-upon-Tyne, August 28th, 1893.

ENGINEERS.—GENERAL STATEMENT, JULY 31, 1893.

Assets.

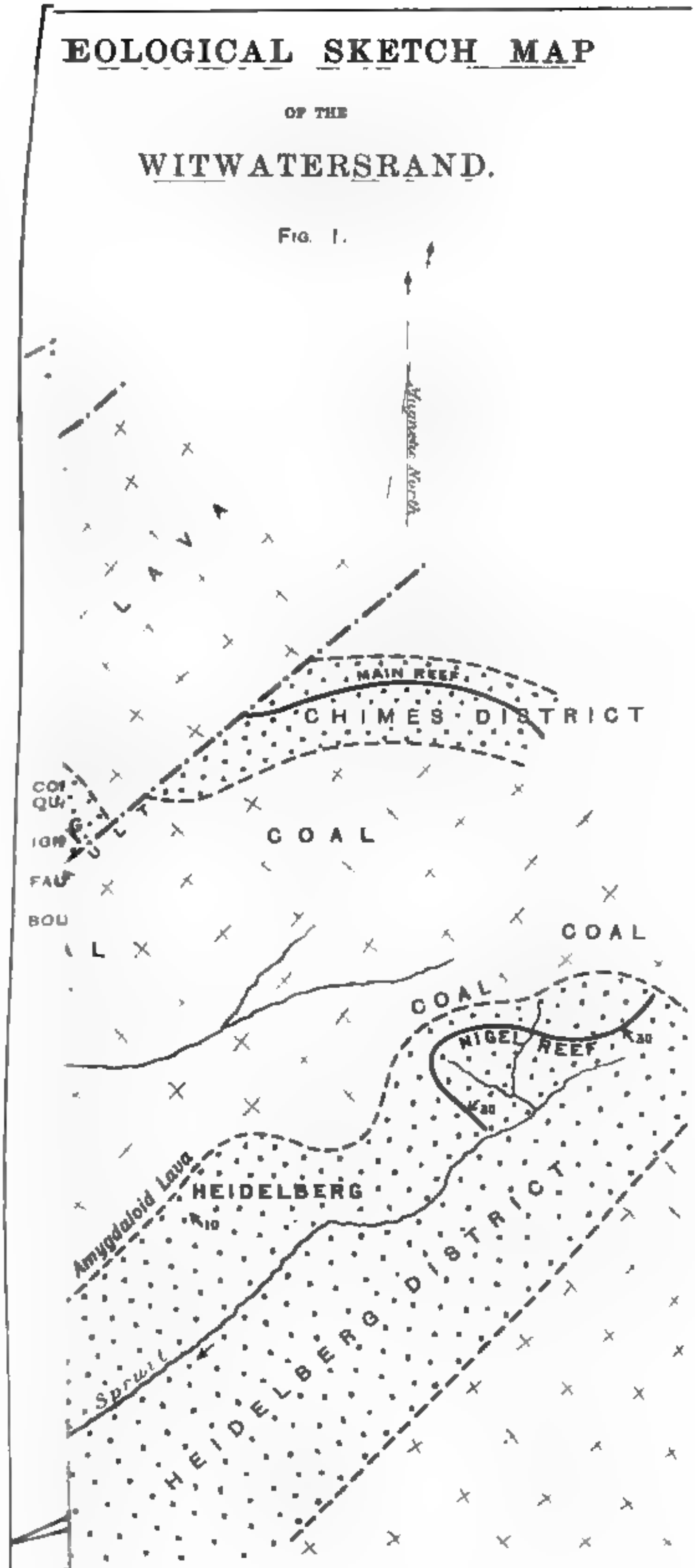
	£ s. d.	£ s. d.
Balance at Bank, etc.	125 1 11	
„ in Treasurer's hands	20 7 1	
		145 9 0
Subscriptions Unpaid, Year ending July 31, 1893—		
Federated—		
North Staffordshire Institute of Mining and Mechanical Engineers	52 0 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	3 15 0	
		55 15 0
Special Call Unpaid—		
North Staffordshire Institute of Mining and Mechanical Engineers	9 19 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	12 5 0	
		22 4 0
Excerpts Unpaid—		
North Staffordshire Institute of Mining and Mechanical Engineers	7 13 6	
South Staffordshire and East Worcestershire Institute of Mining Engineers	3 0 3	
Members, etc.	0 16 11	
		11 10 8
Transactions Sold—		
North Staffordshire Institute of Mining and Mechanical Engineers	1 1 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	5 7 6	
Members, etc.	0 15 0	
		7 3 6
Advertizements to July 31st, 1893, outstanding		177 19 2
		420 1 4
Transactions—		
5 Volumes at 13s. 6d.	3 7 6	
12 „ 10s. 6d.	6 6 0	
6 „ 10s. 3d.	3 1 6	
6 „ 8s. 6d.	2 11 0	
778 „ 7s.	272 6 0	
2,791 Parts at 1s.	139 11 0	
1,713 Copies, Excerpts of Papers, etc.	Nil.	
		427 3 0
		£847 4 4

The PRESIDENT said that the question of the origin of the gold could only be discussed by those who had a full knowledge of the exact conditions in which it was found. They all had a great interest in the production of gold, and they knew what an important bearing it had on commerce. They also knew how much development there had been in the science of gold-mining and in the treatment of gold ores. He hoped that benefit might result from the papers they had had on the subject, and moved a vote of thanks to the author of this paper for bringing the subject before them.

The vote of thanks was agreed to.

Mr. WALCOT GIBSON, in reply, stated that he had avoided, as far as possible, introducing any controversial matter as to the origin of the gold. It was a very difficult problem, and as yet far from being satisfactorily explained. He was inclined to believe that the gold was originally of alluvial origin and had been dissolved and redeposited in the manner stated in his paper. He thought that the existence of the fault north of Johannesburg and the one running up the Klipriversberg valley was important as defining the limits of the richest gold-bearing zone in the immediate vicinity of Johannesburg. Within these limits it was almost certain that payable reefs would be found at workable depths. He wished to acknowledge the vote of thanks.

The SECRETARY read the following paper, by Mr. D. Murgue, on "The Friction of, or Resistance to, Air-currents in Mines":—


EOLOGICAL SKETCH MAP
OF THE
WITWATERSRAND.
Fig. 1.
Magnetic North
LAVA
MAIN REEF
CHIMES DISTRICT
FAULT
COAL
COAL
COAL
NIGEL REEF
HEIDELBERG
Amygdaloid Lava
Spruit
HEIDELBERG DISTRICT

GEOLOGY OF THE SOUTHERN TRANSVAAL.

By WALCOT GIBSON.

The importance of the Transvaal gold-fields is now fully established. Over 1,200,000 ounces of gold were obtained last year from the Witwatersrand alone. The main reef has been proved in several deep levels, and the pyritic ores have been very successfully treated. With coal close at hand, and with rapidly increasing railway communication, the value of these gold-fields cannot be questioned. An account of the geological structure of the country may not be out of place, since it clearly shows that the value of the Transvaal as a mineral-producing country is not overestimated.

The Southern Transvaal forms a portion of the high veld of South Africa. Igneous rocks, in the form of intrusive sheets, dykes, and necks, cover extensive tracts. The coal-bearing strata come next in importance as regards the area occupied by them, while from beneath the igneous rocks and coal-measure sandstones, auriferous conglomerates crop out in several localities.

North of Johannesburg, an extensive tract is composed of metamorphic rocks, consisting of gneiss and granite with several varieties of altered igneous rocks, chiefly basic in character—gabbros, basalts, etc. These belong to the oldest formations in the Transvaal. They were much denuded before any strata were deposited on them, and they undoubtedly formed the solid unyielding mass against and over which the gold-bearing strata were thrust.

Few exposures are met with near Johannesburg, since the rocks form gently rolling grass-covered country and seldom rise into hills. They can best be seen on the Houghton estate, where they consist largely of micaceous acid gneisses, crossed by quartz-veins and pierced by graphic granite, remarkable for the relatively large size of the quartz and felspar-crystals. The remainder consists of quartzites and highly contorted hornblende and mica-schists ; chlorite-schists are not uncommon. Talc and asbestos are abundantly developed, but the fibre of the asbestos is very short.

In some geological sections these metamorphic rocks are represented as granites of newer date than the auriferous conglomerates, which are stated to owe their inclination to the upheaval of the granite. This is certainly not the case, for they are far older than the conglomerates, and so far from being upheaved, constitute the solid rock against which the conglomerate series is thrust.

The next oldest rocks consist of quartzites, shales, and conglomerates. They call for special attention, as it is in some of the conglomerate-bands that the gold is found. For convenience of description, the entire series of quartzites, shales, and conglomerates will be called the "banket formation" in this paper, and the bands of "banket" or conglomerate forming the north reef, main reef, and south reef, will be grouped together as the main reef.

The banket formation is well developed in the neighbourhood of Johannesburg, where numerous exposures and mines give excellent sections. What appear to be the lowest beds consist of quartzite and quartz-rock, succeeded by red-and-black hardened shales. The quartzites form the high ground north of Johannesburg, the valleys being excavated in shales. The lowest bed consists of nearly pure quartz-rock about 150 feet thick. In a drift into the base of this bed on the Houghton estate, it is clearly seen that the quartz-rock is an altered sediment which has been thrust over the metamorphic rocks. A narrow conglomerate-band, still recognizable as such, proves this conclusively. The pebbles are seen to be elongated in one direction; and the original matrix flows round the pebbles, forming a rock resembling an augen-gneiss.

The quartz-rock is overlain by intensely hardened shales. On the road leading from Johannesburg to the Houghton mine, and near the gap in the ridge formed out of the quartz-rock, the shales are caught up and twisted between bands of quartzite.

Overlying the shales are three beds of quartzite, the two lowest being overlain by red-and-black shales. The average dip of the quartzites is 55 degs. south, but the shales generally have a higher dip. Looking at these quartzite ridges from the high ground behind Johannesburg, the conclusion seems inevitable that they are one band repeated by overfaulting. The beds of shale and quartzite are identical in thickness and composition, while the wedge-shaped nature of the bands of quartzite is most distinct.

Direct evidence that these beds are folded and overthrust is afforded by the shales. Behind the Landrost's house, close to the road leading to Auckland Park, the shales are seen to be folded, and a large block shows

crumplings and twisting and minor thrust-planes as distinct as those in an Alpine schist. There can be no doubt that at this particular spot some powerful force has acted, strong enough to fold the shales. That this is not a mere local phenomenon, but is due to a general movement affecting the whole series, becomes evident as the shales are traced along the strike. By walking eastwards along the outcrop of the shales the dip is plainly seen to have passed the normal, so that the southerly dip is only an apparent one.

To the west of Johannesburg, the quartzite-bands extend as far as Krugersdorp, but to the east they end off one after another, against a powerful thrust-fault running up the Doornfontein valley. This fault separates the quartzites and shales from the main reef series. If there be no fault here, the main reef must be unconformable to the quartzites and shales, for while behind Johannesburg the quartzites dip at 45 degs., the main reef is nearly vertical. But an unconformity is not admissible, since the strike of the main reef remains constantly parallel to that of the quartzites.

Resting on the quartzites and shales, but with a faulted junction, as just shown, is an apparently vast thickness of sandstones and conglomerates, towards the base of which two or more bands of conglomerate occur, constituting the famous main reef, the richest and most constant gold-bearing zone of the Witwatersrand. These measures occupy the ground between Johannesburg and the Eagle's Nest, and extend from Boksburg to Krugersdorp. On the northern outcrop the beds have a high dip (85 degs. to 60 degs.) near Johannesburg. They appear to flatten out gradually to the south till they come to lie at an angle of 15 degs. This flattening out southwards has led all who have written on the subject to consider the beds as lying in a simple unbroken syncline, and if the faulted relation of the strata to the underlying quartzites and shales be not recognized, and if attention be only paid to surface outcrops, such a conclusion is inevitable. A careful examination of the strata, more particularly those composing the main reef, reveals abundant proof that great pressure has been exerted, and that under its influence the beds have in many instances given way, and thus disturbed the synclinal arrangement.

The main reef is composed of four beds of conglomerate, each averaging 4 feet in thickness. They are distinguished as north reef, main reef, with its leader, and south reef. This distinction of four reefs refers only to their relative position, for little mineralogical difference can be detected other than of quite local application. All four reefs consist of a

conglomerate composed almost exclusively of pebbles of white quartz and quartzite. The south reef is generally considered to contain a greater percentage of pebbles of black quartz, but this distinguishing feature can only be applied to one or two mines. Whatever difference there is, it is so slight as to be practically inappreciable. The south reef, as a rule, carries the most gold, but there are exceptions.

It is important to notice that, traced in depth, the loose, surface-red conglomerate becomes a hard, blue, compact rock, crowded with crystals of iron pyrites, while the same change affects the country rock, which from being a soft red sandstone at the surface becomes converted on the lower levels into a compact quartzite or a hard micaceous schistose rock, containing numerous crystals of iron pyrites.

The foot-walls and hanging-walls present smooth surfaces, and the division between the coarse conglomerates and the fine-grained country rock is clear and sharp, and devoid of irregularities.

A microscopical examination of the pyritic conglomerate from the Robinson mine reveals the following interesting structures. In ordinary transmitted light numerous lines of strain are observed to pass across both pebbles and matrix, showing that the rock has been subjected to pressure subsequent to consolidation. Lines of bubbles are developed in the quartz-pebbles and matrix. The iron pyrites is seen to be of secondary origin. Polarized light shows that what look like two separate pebbles are really one pebble broken asunder, secondary quartz being developed between them. It is not uncommon to find that two pebbles lying near to each other are in optical continuity. Many of the pebbles are very much broken, displaying under the microscope a mosaic of colours.

Microscopic examination thus shows that the strata have been subjected to great pressure, and fully confirms the results obtained from a stratigraphical investigation. The pressure has evidently been sufficient to break and crush the pebbles and to develop lines of strain, but it was not intense enough to roll the pebbles out in the direction of movement. The result of the pressure has certainly been to make a compact rock out of an original incoherent conglomerate.

It now remains to show how far the beds in mass have been affected by the movements.

In the mines near Johannesburg, there is little evidence of faulting, but since the dip of the beds is high, and the faults are chiefly of a reverse kind, the horizontal displacement of a really powerful fault is not great and affects the miner very little. Still, faults are more numerous than is supposed, for since they do not interfere with mining, they are

not noticed, but the accumulated effect of numerous very small overfaults must be great. It is in this way that the beds have accommodated themselves to the smaller space they were compelled to occupy. The beds of conglomerate and sandstone could not fold like the shales, but as they became more and more compact under pressure, the individual beds snapped and rode over each other. The result of the overfaulting is to bring the beds closer together, at the same time carrying them nearer the surface.

Besides causing the beds to become closely packed, pressure has effected another change in the original condition of the conglomerates and sandstones. In a hand-specimen of the banket, one of the most characteristic features is the coating of each pebble with a thin film of talc. There is little doubt that this mineral is manufactured by slow and continuous pressure out of the original felspathic material of the matrix.

The sandstones have been affected in the same way. The sand-grains have been partially rounded till the rock was converted into a quartzite, and where the pressure was great enough, a large quantity of silica segregated out in the form of quartz-veins. The felspathic material was converted into a talcose mineral, which arranged itself in layers at right angles to the direction of pressure, giving the rock a schistose structure.

Further evidences of the strata having been intensely squeezed is given by the 200 feet level of the Henry Nourse mine and by the disposition of the strata forming Jeppes hill. In the cross-cut north, on the 200 feet level of the Henry Nourse mine, five wedge-shaped reefs have been cut through. They are veined with quartz and intensely hard. The country rock consists of quartzite and chlorite-schists, the latter being much crumpled and puckered up. In Jeppes hill the evidence of thrusting is still stronger. In a transverse gully leading from the Doornfontein valley to the summit of the hill the schistose nature of the beds and their wedge-shaped arrangement are most clearly demonstrated. The strata consist of quartzites, mica-schists, and several bands of conglomerate. The upper part of the series is conglomeratic and is overlain by shales and quartzites, identical with those previously described as lying beneath the main reef north of Johannesburg. This apparent reversal of the sequence is plainly due to overfaulting. The position of the fault is marked by a 2 feet band of white quartz.

Evidences of thrusting can be obtained in any mine along the northern outcrop, if the beds are carefully examined. The country rock in all cases is either a quartzite or schistose rock, and the strata are frequently broken through by small overfaults.

It would be superfluous to bring forward further evidences that the strata have been thrusted.

An examination of the main reef, as developed in the mines east and west of Johannesburg. shows that the conglomerate-bands form lenticles in the encasing rock. Thus, in the Salisbury mine, the main reef and its leader are 24 feet apart. In the Robinson mine they have come together, and farther west they cannot be recognized as separate bands. Traced still farther westward in the Durban Roodepart and Princess mines, the reefs have thinned out, the south reef being represented in places by a thin line of pebbles.

East of the Jumpers mine, and again west of the Princess mine, the distinction into main and south reef vanishes. Other reefs of similar lithological character to parts of the main reef (but never so rich in gold) take their place or represent them.

At Krugersdorp and Boksburg, the westerly and easterly extremities of the outcrop of the main reef, the beds assume a southerly strike, but they are soon cut off by broad dykes of basic igneous rocks.

South of Johannesburg the dip of the main reef series gradually decreases to the Klip River Spruit. The Klipriversberg Gold Mining Company, judging from the slickensided material thrown out on the surface, seem to have sunk down on a fault, and there is evidence that this fault is continued along the Klip River Spruit. South of this fault auriferous conglomerates crop out, having a constant dip of 15 degs. To what part of the series these conglomerates belong, it is impossible to decide. They may lie above or below the main reef, but it is certain that the main reef continues up to the fault. From the northern outcrop to this fault is a distance of nearly three miles. This distance represents the breadth of the band upon which the main reef will be found to exist at workable depths. The depth at which the reef will be struck will always be uncertain. In some cases overfaulting will bring the beds comparatively close to the surface, and in all cases the reef will be struck at a shallower depth than one calculated by the dip on the northerly outcrop.

South of the great igneous outflows of the Eagle's Nest, the banket formation crops out to form the black reef, but the author only crossed the reefs once and had no opportunity of examining them.

Conglomerates, sometimes auriferous, but evidently belonging to the same formation as the Witwatersrand conglomerates, are found outside the Witwatersrand. The most important is the conglomerate forming the Nigel reef in the Heidelberg district. It is impossible to correlate this

Federated Institution of Mining Engineers
Transactions 1893-94

To illustrate Mr. Walcot Gibson's Paper on "The Geology of the Southern Transvaal."

Vol. VI. Plate IV.

Fig. 3.—Diagram Section across Main Reef.

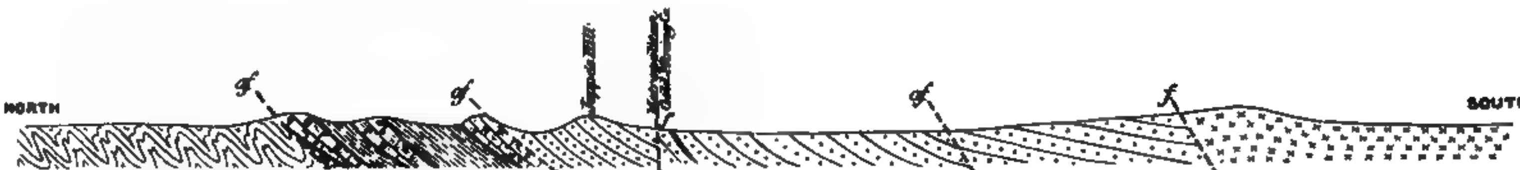


Fig. 4.—Diagram Section across Southern Transvaal.

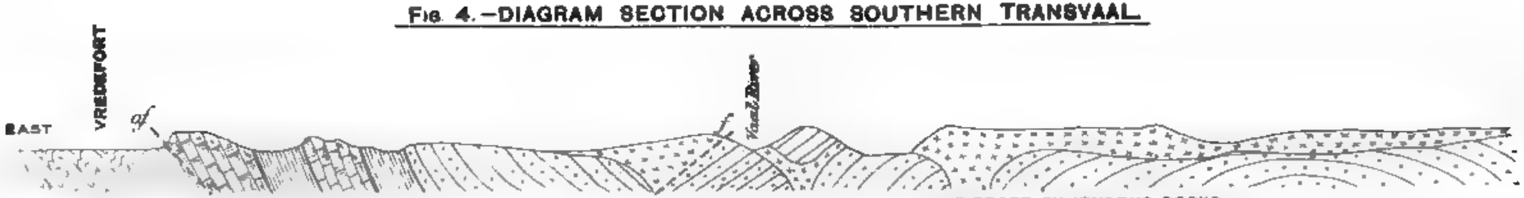
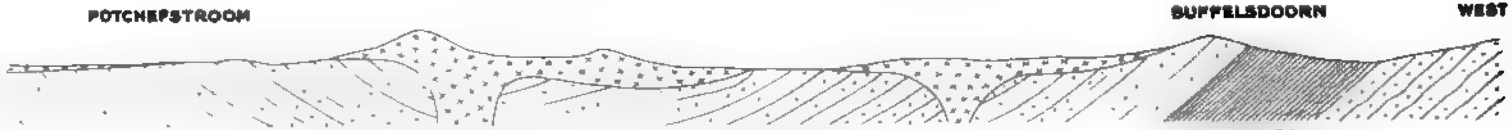


Fig. 4 Continued.



Andw Reid Sons & Co Lithos Newcastle

Mining Institute of Scotland
Transactions

Vol. XV. Plate II

(2) The strata are impregnated with iron pyrites. The gold is chiefly confined to the conglomerates or to their immediate vicinity. It is commonly found in the matrix and rarely in the pebbles. Though the pyrites of the conglomerates carries gold, the pyrites of the country rock is either barren or contains the merest trace of gold. The gold, except near the surface, is always in a crystalline condition. The conglomerates are not all of equal richness, but all become slightly richer in depth.

(3) The amount of gold present bears no relation to the inclination of the strata or to the proximity of igneous rocks, or to the thickness of the conglomerate-bands. A reef only a few inches thick often carries two or more ounces of gold, while one 7 feet thick is barren, and this is so of reefs only separated by 100 feet of rock. Vein-quartz is abundant, but though the affinity of gold for quartz is well known, these quartz-veins, which are crowded with crystals of iron pyrites, do not contain gold.

Any theory that is advanced must be capable of explaining all the above well-ascertained and undoubted facts.

Three theories have been brought forward :—

1. The gold is alluvial and was deposited in its present condition.
2. It is of secondary origin, due to infiltration from above or below.
3. It is partly alluvial and partly due to infiltration. The infiltrating solutions are considered to have dissolved the original gold, and then re-deposited it in a crystalline condition, and at the same time deposited fresh gold brought up in solution.

The first view is manifestly inadequate to explain the facts. It seems almost incredible that alluvial gold could be so uniformly distributed over so wide an area and in a crystalline condition.

The second theory also fails to explain many of the facts. Why should the gold be confined to the conglomerates, as it is evident from the country rock containing iron pyrites that the infiltrating waters had free access to the rocks; and how is it that a thick and incoherent conglomerate contains little or no gold, while an adjacent compact narrow band is rich in this metal? Supposing the gold in solution to have entered the rocks either anterior or posterior to the solutions which deposited the iron salts, it is hard in either case to understand why it chose a compact rock like the conglomerates in preference to the highly fissured quartzites.

A modification of the third view seems to explain most of the facts. The gold is of alluvial origin, and was confined to the conglomerates. Long after the tilting and movement of the beds, and probably at the time of the great igneous intrusions, a solution containing iron salts

permeated the strata wherever it could penetrate. The original gold in the conglomerates was dissolved and redeposited mostly in the conglomerates, but in some cases along the margin of the conglomerate-bands. On any other view it is difficult to account for the gold being almost exclusively confined to the conglomerates, and for the great disparity in richness of nearly adjacent reefs.

Explanation of the Plates.*

Plate III., Fig. 1.—Geological sketch map of the Witwatersrand.
 „ Fig. 2.—Diagram section showing effect of overthrust faulting.
Plate IV., Fig. 3.—Diagram section across main reef.
 „ Fig. 4.—Diagram section across Southern Transvaal.

The President said that as a descriptive paper it was very valuable, but it certainly involved a great deal of controversial matter as to the origin of the gold.

Mr. D. A. Louis (London) said that many mining engineers, who visited the Transvaal, seemed to think it incumbent on them to write papers and promulgate new theories as to the origin of the conglomerates and the gold in them. It was, therefore, agreeable to find, in the present paper, what appeared to be an actual record of geological features as observed by the author and untrammelled by preconceived theoretical notions. Such a record was undoubtedly of great value, more especially to those who had not visited the region, and particularly when sections were forthcoming. Time would not permit of comment on the numerous details furnished in the paper, although one would be tempted to dwell on many of them; it was, however, interesting to note the abundant and strong evidence adduced in support of the view that the rocks have been disturbed and altered since the conglomerate-beds were deposited. His (Mr. Louis') microscopical examination of some specimens of banket led him to differ from the author as to the pyrites being wholly of secondary origin; but, in conformity with views expressed by him (Mr. Louis) on a previous occasion, he regarded with favour the view set forth in the final paragraph of Mr. Gibson's paper so far as it related to the gold having been originally alluvial and having been subsequently redissolved and redeposited; and added that it was satisfactory to find the writer's extensive observations leading him (Mr. Gibson) to this conclusion.

* Figures 1 and 2 are in part reproductions of diagrams used by the author in illustration of his paper on "The Geology of the Gold-bearing and Associated Rocks of the Southern Transvaal," published in the *Quarterly Journal of the Geological Society*, vol. xlviii., Plates X. and XI.

The PRESIDENT said that the question of the origin of the gold could only be discussed by those who had a full knowledge of the exact conditions in which it was found. They all had a great interest in the production of gold, and they knew what an important bearing it had on commerce. They also knew how much development there had been in the science of gold-mining and in the treatment of gold ores. He hoped that benefit might result from the papers they had had on the subject, and moved a vote of thanks to the author of this paper for bringing the subject before them.

The vote of thanks was agreed to.

Mr. WALCOT GIBSON, in reply, stated that he had avoided, as far as possible, introducing any controversial matter as to the origin of the gold. It was a very difficult problem, and as yet far from being satisfactorily explained. He was inclined to believe that the gold was originally of alluvial origin and had been dissolved and redeposited in the manner stated in his paper. He thought that the existence of the fault north of Johannesburg and the one running up the Klipriversberg valley was important as defining the limits of the richest gold-bearing zone in the immediate vicinity of Johannesburg. Within these limits it was almost certain that payable reefs would be found at workable depths. He wished to acknowledge the vote of thanks.

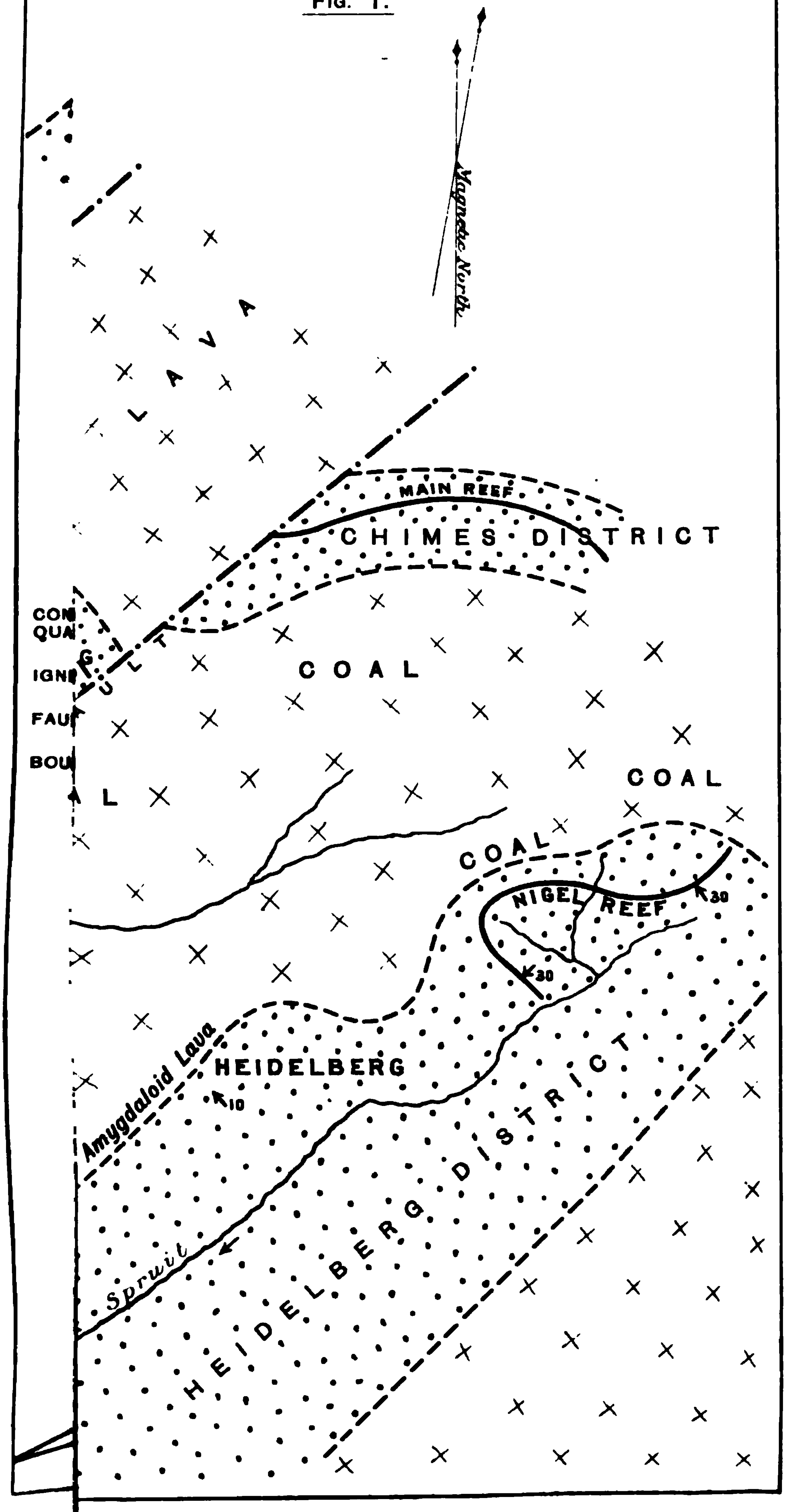
The SECRETARY read the following paper, by Mr. D. Murgue, on "The Friction of, or Resistance to, Air-currents in Mines":—

EOLOGICAL SKETCH MAP

OF THE

WITWATERSRAND.

FIG. I.



To illustrate Mr. Walcot Gibson's Paper on "The Geology of the Southern Transvaal."

Fig. 3.—Diagram Section across Main Reef.

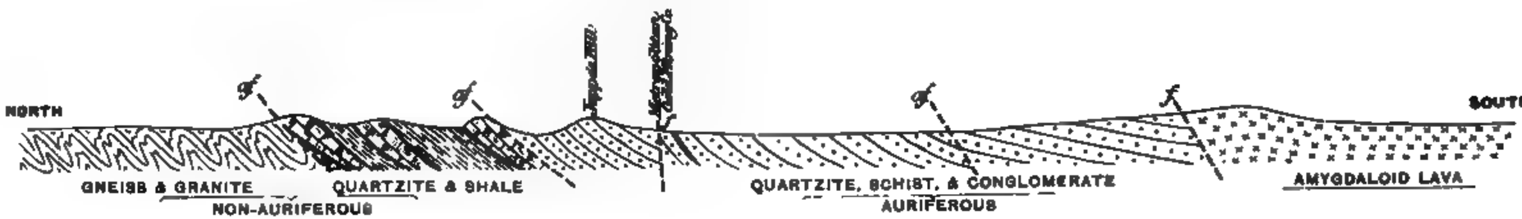


Fig 4.—Diagram Section across Southern Transvaal.

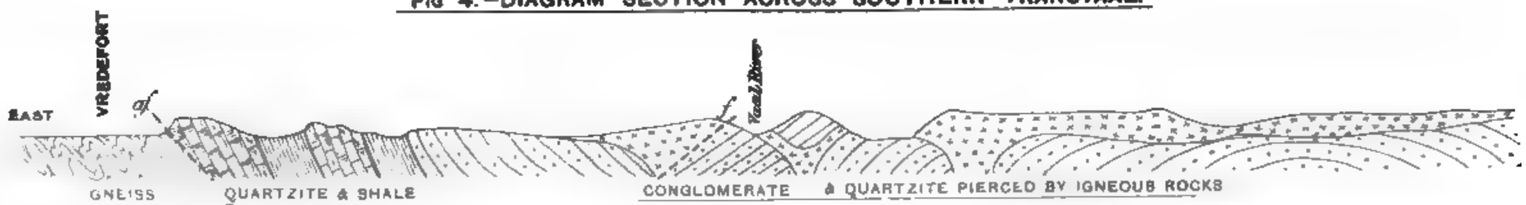


Fig. 4 Continued.

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THE FRICTION OF, OR RESISTANCE TO, AIR-CURRENTS IN MINES.

BY DANIEL MURGUE.

1.—THE DEPRESSION OR WATER-GAUGE.

The circulation of air in the passages of a mine is accompanied by a gradual and continuous diminution of its pressure between the points of its entry and of its exit, owing to its friction against the more or less uneven and rugged walls of its course.

By way of analogy with the behaviour of water and gas, we will adhere to the classical term of water-gauge (loss of pressure) for this fall. The term depression or water-gauge will be used for this loss of head or pressure of the underground air-currents, and, in accordance with custom, it will be measured by the height of the column of water which balances it. Throughout this paper, this height will be designated by the letter h, and will be expressed in inches.

The conception of the friction of air against the sides of the passage of a mine is very different to that of the friction of the solid surfaces of machines. It is not here a question of surfaces, more or less greasy or lubricated, sliding one upon another, but an incessant restoration of velocity and of direction to innumerable particles of air, which are dashed against and deflected by the rough walls of the passages. In such conditions it can easily be shown that the pressure lost in maintaining the current, or in other words the water-gauge must increase in direct proportion to the density of the air and to the square of its mean velocity.* On the other hand it seems evident that this loss of pressure must be proportional to the extent of the rubbing surface. If then a numerical coefficient be introduced, which allows for the differences, which may present themselves, between one gallery and another, the inequalities of the sides, and the bends and strictures of the passages; all the elements necessary to mathematically define this amount are at hand. The value may be very simply obtained by expressing as an equation, the equilibrium that should be maintained between the opposing forces.

* Appendix B.

Let A to B (Fig. 1, Plate V.) represent the portion of an horizontal gallery of a length L, in which the air circulates in the direction of the arrow, and whose profile is sufficiently regular so that it may be assumed to have a constant average section, and consequently to have an uniform average velocity. It will be assumed that the density of the air is also constant, the variations of pressure in comparison with the total pressure of the atmosphere being inappreciable. At A the pressure is H; at B, the lower pressure H′; and the difference of H — H′ is the loss of pressure h required.

The force exerted at A, in the direction of the current, is equal to sH, s being the average area of the gallery in square feet; the opposing force at B is sH′, and, consequently, the resultant motive force is the difference of $s\mathrm{H} - s\mathrm{H}' = sh$.

The resistance to be overcome is proportional, as already mentioned, to the extent of the rubbing surface, that is to the product Lp, of the length of the gallery of an uniform section in feet by its mean perimeter in feet; it is also proportional to the density, or, to be more exact, to the weight δ of the cubic foot of air in circulation, to the square of its mean velocity v in thousands of feet per minute, and, finally, to a coefficient k, whose numerical value varies according to the nature of the walls of the gallery in question and its bends and strictures.

The force and the resistance thus defined may be expressed as an equation:—

$$sh = k\,\mathrm{L}pv^2\delta;$$

and consequently

$$h = k\,\frac{\mathrm{L}pv^2\delta}{s}.$$

This equation measures the loss of pressure for a length L of the airway under consideration.

Some writers, and in particular Mr. Devillez, in reproducing this formula, have excluded the weight of the air δ, owing, no doubt, to the consideration that in practice the variations of the density of the atmosphere of mines are of little account in comparison with the uncertainty, which exists in each particular case, as to the numerical value of the coefficient k.

If this view be approved, many observations and calculations will be avoided; it will be convenient to substitute, in the preceding equation, the weight of air δ by the ratio $\frac{\delta}{\delta_0}$, δ_0 representing the ordinary usual weight of a cubic foot of the air of a mine, say 0·075 pound:—

$$h = k\,\frac{\mathrm{L}pv^2\delta}{s\delta_0}.$$

Hence, if the variations, large or small, which may be produced in the density of the air, be neglected; it may be assumed that $\delta = \delta_0$, and we may return (without any change in the value of k) to the more simple formula of Mr. Devillez:—

$$h = k\frac{Lpv^2}{s}.$$

The loss of pressure may be represented by an equation, whose unknown factor is k; and the preceding equation may be expressed as follows:—

$$k = \frac{hs\delta_0}{Lpv^2\delta};$$

an expression which shows that if the loss of pressure, the length of the airway, its mean area, its mean perimeter, the mean velocity of the air, and its specific weight are known, the numerical value of the coefficient k can be readily deduced.

The experiments to be described in this paper were made for the purpose of determining the value of the coefficient k for three well-defined classes of airways, viz.:—Galleries unsupported, galleries lined with masonry, and galleries propped with timber.

The present experiments are by no means the first which have been made upon this interesting question; attempts, more or less successful, have been made at different times and will now be summarized.

For many years, mining engineers used the figures obtained from the old experiments of Mr. d'Aubuisson on the flow of air in iron pipes. The value being:—

$$k = 0{\cdot}00039.$$

This value could only be applied with considerable reserve to the case of mine galleries, owing to the comparative importance of the area of these passages, and especially owing to the nature of their sides. Consequently Mr. Raux conducted, in 1866, the experiments which are recorded by Mr. Devillez in his work on the *Ventilation des Mines*.*

These valuable experiments were made at the Crachet-Picquery, Forchies, and Grand-Buisson collieries in Belgium, where the air entering the mines by the coal-drawing shaft passed the separation-doors upon which the water-gauge was placed, and then traversed a series of galleries following a descending direction until it reached the main level; from this point the air went through the working-places, and finally passed into the upcast shaft at the level of the separation-doors. The water-gauge indicated the total loss of pressure, and as the experimental mines each consisted of a number of galleries, of different lengths, sections, and

* Pages 32 to 34.

perimeters placed end to end, in each of which the air moved with a different velocity, the recorded values of h, L, s, p, and v, afford all the data requisite for the calculation of the mean value of the coefficient k.

Mr. Raux's experiments yielded the following values of k:—

At Crachet-Picquery	0·00174
At Forchies	0·00157
At Grand-Buisson	0·00167
And the average	0·00166

In other words, a depression measured by 0·00166 inch of water is required to propel air at a velocity of 1,000 feet per minute through a gallery whose rubbing surface is 1 square foot.

Mr. Devillez considered this value to be a little too small, owing to the effects of natural ventilation and adopted the following value as being applicable to the ordinary galleries of a mine:—

$$k = 0{\cdot}00180.$$

This mean value of the coefficient of friction does not take into account the resistance which the various portions of the airways may offer to the circulation of the air. It seems evident, *a priori*, that great variations must exist between one class of gallery and another, and particularly in the three types previously defined.

The late Mr. J. J. Atkinson considered that the value of :—

$$k = 0{\cdot}00417,$$

and Mr. Hawksley:—

$$k = 0{\cdot}00047.$$

These values vary widely from that proposed by Mr. Devillez. Under these circumstances, without wishing to depreciate the labours of his predecessors, it appeared to the writer that the interesting question of the rate of the loss of pressure in mine galleries was far from being completely solved, and that further experiments were required.

The writer, therefore, determined to undertake the repetition of these troublesome and difficult experiments, and believes, at least, that he used sufficient care and precaution to ensure the results obtained being free from error or liability to dispute.

2.—The Experiments.

Description of the Experiments.—The method applied to the numerical determination of the coefficient of friction may be shortly explained.

Let X Y be a length of horizontal gallery whose area and perimeter are almost uniform, and through which the air passes in the direction shown by the arrow (Fig. 2, Plate V.). From the same vertical plane M N, two lines of pipes are placed against the sides, one very long

M A, and the other very short N B, in such a manner as to include between their open ends A and B, a length of about 300 feet.

The ends M and N are connected by means of indiarubber tubes, with the two arms of an ordinary water-gauge, consisting of a U-shaped tube partially filled with water. The stagnant air, filling the tubes, will transmit to the water-gauge the pressures existing at the open ends A and B, more or less modified by the action of the air on the orifices of these tubes. But as this action is exerted at A and B under identical conditions, it is the same at the two points and is in equilibrium, and the difference of level of the water in the gauge will be the exact measure of the difference of the pressures at the points A and B, that is to say of the loss of pressure due to the circulation of the air in the airway A B.

The result will be the same in the case of an inclined gallery, for the column of air in circulation, and those filling the tubes, having the same pressure and the same temperature, are in equilibrium, and do not affect the readings of the water-gauge. If then, at the same time, observations are made of the loss of pressure, the velocity and temperature of the air, the atmospheric pressure, and the degree of moisture, together with measurements of the airway A B, its length, its mean section, and its mean perimeter, these values may be substituted for the symbols in the formula :—

$$k = \frac{hs\delta_0}{Lpv^2\delta},$$

and, consequently, the numerical value of the coefficient k may be calculated.

Pipes.—Wrought-iron pipes were used, connected by screw-joints. Their internal diameter was 1·06 inches (27 millimetres). They were sufficiently flexible to pass round the sinuous portions of the galleries. The open ends A and B were fitted with right-angled elbows, whose orifices were placed near the side of the gallery, and protected by a small screen from the impact of the air. The author had no very clear ideas as to the best arrangement to be adopted for these tests of pressure; but he considers that the disturbing action, exercised at the two ends of the airway A B would be in equilibrium, and would not affect the observations. The ends M and N were fitted with reducing pipes of small diameter, to which the indiarubber tubes communicating with the water-gauge were connected.

All joints were covered with putty, and observations were only commenced when the apparatus was found to be perfectly airtight.

The distance A B will be called the airway throughout this paper.

Water-gauge.—The essential point for ensuring the success of the experiments was the possession of a very delicate differential water-gauge. It was recognized that the losses of pressure to be measured would frequently be less than 0·04 inch (1 millimetre) of water, and that under such conditions the measurements would have been valueless, unless they attained an exceptional degree of accuracy.

There exist numerous types of wheel-geared differential water-gauges, but, in general, the amplification is obtained by the aid of artifices, which entail passive resistances destructive to their sensitiveness. This defect is recognized when equilibrium is re-established in the water-gauge, by the failure of the needle to return to zero. Consequently the ordinary U-tube water-gauge in which the liquid is free to place itself in equilibrium with the pressures affecting it, was used in the experiments, with the aid of a microscope in taking the readings (Figs. 3, 4, and 5, Plate V.).

The branches of the U-tube consisted of two accurately gauged glass bottles of the same height, but of very unequal diameters, connected at the bottom by an indiarubber tube, and half filled with water. Their orifices were closed with corks fitted with glass-tubes and penetrating deep enough into the neck so as to form a sort of trough which was filled with water; the indiarubber tubes connected with the tubes of the airway dipped into this water-seal, which ensured perfect air-tightness, a necessary condition to ensure the accuracy of the experiments.

A wooden collar was attached to the neck of the large bottle so as to support the tubes.

Owing to the difference of the diameters, the variation of level was produced almost entirely in the small bottle, where the readings were taken, it being sufficient to increase them in a ratio, determined once for all, by taking account of the depression of water in the large bottle.

The internal diameter of the small bottle was 1·969 inches (50 millimetres), and of the large one 6·417 inches (163 millimetres). The ratio of increase, directly measured, was equal, after three concordant observations to 1·096.

n front of the small bottle and nearly touching it, was a microscope fitted with cross-hairs and magnifying 50 times, mounted on a special stand. An essential point was to render the base of the meniscus, formed by the contact of the water and the glass, clearly visible in the microscope. For this purpose, a white line was drawn on a black ground arranged behind the bottle, lower than the level of the water, and formed by a glass tube filled with paint. This tube, strongly illuminated by a lamp,

reproduced its image by total reflection at the base of the meniscus, in the shape of a slender brilliant thread, upon which the cross-hairs of the microscope could, without hesitation, be placed.*

In order to measure the vertical movements of the microscope, the micrometer screw connected with the support might have been used, but various reasons led to a different arrangement.

The microscope was fitted parallel to its axis in an eccentric, turning on a bearing mounted on the strong slide of the stand. This eccentric carried, in front, a pointer 9½ inches (240 millimetres) long, whose extremity moved over a graduated arc. The axis of the microscope did not coincide with that of the eccentric, but was placed at a horizontal distance of 0·236 inch (6 millimetres), so that when the pointer traversed a horizontal arc from left to right, the cross-hair of the microscope described an ascending vertical arc, whose amplitude was forty times less.

To regulate the instrument, equilibrium is established of the pressures in the two tubes of the water-gauge, then the pointer is pushed against the left stop at the zero of the graduated scale, and by means of the screw placed at the bottom of the slide the microscope is raised to the common level of the water in the two tubes.

If then proper connexion be made between the water-gauge and the two lines of pipes in the airway, the water will rise in the small bottle, and the microscope can be made to follow its movement by altering the position of the pointer from left to right, and the amount of alteration of level can be read with a multiplication of forty times.

The graduation of the arc in degrees and minutes does not give directly the height of the column of water, but a trigonometrical function which differs little from it. It is necessary therefore to make a preliminary adjustment, which is effected by substituting for the small bottle a scale divided to 0·02 inch (½ millimetre), and then taking readings for each of these divisions. If the arcs be drawn as abscissas and the heights as ordinates, a mean is obtained which enables one graduation to be converted into the other with the greatest ease.†

The arc only allowed of the observation of alterations of level of less

* For perfect accuracy, the white line should rise and descend with the eye-piece, in order to always maintain the same inclination to the incident ray. But with the slight differences of level observed, the error arising therefrom was absolutely imperceptible.

† The same data could be used to determine the constants of a suitable formula, but the graphic method is more rapid, and quite as accurate.

than 0·256 inch (6·5 millimetres); for greater heights, the screw of the stand might have been used as a micrometer screw, but as a matter of fact its use was never necessary.

By these arrangements, and the device of the white line which formed however, the only original detail of the system of observation, the primitive water-gauge was converted into an instrument of remarkable sensitiveness. Provided it was placed upon a solid base, say a block of masonry, it was possible to detect an alteration of level of 0·0004 inch (0·01 millimetre). Underground, where the stability was sometimes imperfect, one was generally sure of 0·0008 inch (0·02 millimetre). As a proof of the sensitiveness of the apparatus, it may be mentioned that the entrance of one of the assistants into the airway was immediately detected by a slight elevation of the white line, owing to the increase which resulted from the loss of pressure.

Hydraulic Connexions.—The indiarubber tubes connecting the water-gauge to the lines of pipes were fitted with hydraulic connexions, allowing of the rapid substitution of the pressures under observation and that of the surrounding atmosphere. This was indispensable so as to enable the zero of the instrument to be tested before and after each reading.

Ordinary three-way taps might have been defective, and leakage was to be avoided at all cost; hydraulic connexions were consequently used as shown in Fig. 5, Plate V. The bottom of a small zinc vessel partly filled with water was traversed by four vertical tubes which could be covered two and two by small bells. The lower ends of the four tubes were connected by indiarubber tubes on one side to the two tubes of the water-gauge, and on the other side to the two lines of pipes of the airway, consequently as the bells were lowered or elevated the water-gauge was connected either with the full pressure of the airway or with that of the atmosphere surrounding the apparatus.

A fifth tube ending under one of the bells, and fitted with an indiarubber tube, closed with a spring clip, allowed of air being blown into the apparatus after having first closed the open ends with corks. An artificial pressure was thus established, whose constancy, examined by the help of the microscope, proved its perfect tightness.

Anemometers.—Each observation, as before-mentioned, was accompanied by an anemometric measurement. For this purpose small vane anemometers were used, well protected against the danger of handling, always rather rough in the darkness of mines, and at the same time very sensitive. They perfectly answered the required purpose.

Thanks to the kindness of friends, four anemometers were available for use. They were tested with the greatest care by an arrangement erected in the workshops, and in order that there should be no error in their respective formulæ, the letters A, B, C, and D were painted on the base-plates in large white characters.*

Underground, these instruments were placed on horizontal wooden boards, whose front edge was thinned so as to cut the currents of air without disturbing them (Fig. 6, Plate V.). At each point, two little headless pins, corresponding to two holes, pierced in the base-plate of the anemometers, allowed of their being placed instantly and without hesitation in position.

It is known that the air-velocities distribute themselves capriciously in the cross-section of a mine-gallery, as may be seen by the sketches of curves of equal velocity accompanying this paper. It is important, therefore, to multiply the points of observation, in order to ascertain the true mean velocity. The number varied in the experiments from 20 to 28, according to the size of the area tested, and averaged 24, taken in five rows. The anemometers were placed in the order A, B, C, D, going from left to right and from top to bottom, as in ordinary reading. The observations lasted two minutes, a time which appeared necessary to minimize the slight uncertainty of starting and stopping; but as four anemometers were running at one time, the total duration of one observation did not exceed twenty to twenty-five minutes.

An operation so laborious clearly could not be renewed for each one of the observations of the loss of pressure, which it was proposed to repeat at least twice and often more; on the other hand the presence of the observers in the airway was a serious cause of error, as before-mentioned. It was therefore made only once, at the end of each experiment, and, to accompany the readings of the loss of pressure, the anemometers were placed at four chosen points of the area, and a single observation only made. The numerous measurements which were made proved that variations of the volume of air did not at all modify the configuration of the curves of equal velocity, and consequently that the velocities of the air at the different points of the area of a mine-gallery increase and decrease as a whole, while retaining their relative values. Hence, in order to know the mean velocity of the air in a gallery, it is sufficient to measure the velocity at any point of its section, provided that, by a preliminary test, the constant ratio which exists between the two velocities has been determined.†

* Appendix C.

† Mr. Haton de la Goupillière, *Cours d'Exploitation des Mines*, vol. ii., page 397.

By taking four points instead of one, the guarantee of accuracy of the application of this principle is greatly increased.

The first work on returning to the surface was to calculate all the velocities of the place of measurement, to determine separately the general mean of these velocities, and the mean of those observed at the four chosen points. The coefficient of correction was then determined and applied to the mean of the velocities observed at the same points during the reading of the loss of pressure, and transformed this mean to that which really existed in the airway.

Atmospheric Observations.—The readings of a thermometer graduated to one-tenth of a degree, a standard mercurial barometer,* and a Saussure hair hygrometer furnished the data necessary for calculating the weight of a cubic foot of the air in motion. The Saussure hygrometer only received moderate confidence, as it was found to be an unreliable instrument, and several times its indications had to be corrected.

Choice of Airways.—The field of investigation to be traversed was, so to speak, unlimited, as the galleries of the mine presented the most diverse types in plan, area, and surface. As some limit must be set, twelve was fixed as the number of the experiments, dividing them between the three clearly-defined types, as rectilinear as possible, as already indicated, galleries with native surfaces, those lined with masonry, and those propped with timber.

Some trouble was taken to find, at the Bessèges collieries, lengths of galleries answering exactly to these requirements, viz.:—Presenting a sufficient regularity of area and of the nature of the sides over an equally sufficient length to ensure accuracy of the observations. This length was at first fixed at 300 feet as a minimum, but this rule had to be broken, and a length of about 180 feet was accepted in one of the experiments. It was necessary also that these airways should be completely isolated from the rest of the workings, so as to avoid all ingress or egress of agitated air; lastly, it was necessary to be able to arrange, by opening or shutting doors, a circulation of air sufficiently strong, so that the loss of pressure should have a convenient value.

This last detail has been for us the cause of frequent miscalculations. It is much more difficult than it at first appears to divert a current of air from the airway to which it is in some sort accustomed; the doors, the

* Two aneroid barometers were used at first, regulated beforehand with the standard barometer, but the divergencies of their indications caused their use to be discontinued.

brattice stoppings, the goaves, and even the masonry, are seldom airtight; losses of air exist where least expected, and velocities are obtained considerably less than those desired.

These miscalculations have not prevented, thanks to the sensitiveness of the water-gauge, the loss of pressure being measured with sufficient accuracy to serve as a correct basis for calculations and deductions.

Descriptions of the twelve airways will be given at the same time as the experiments of which they were the subject.

Conduct of Operations.—All the observations were made at night or on Sunday mornings, the only times when it was possible, owing to the cessation of work, to vary the air-currents of the mine.

One of the engineers prepared, in advance, the lines of pipes and placed the anemometer supports and instruments. Although it was matterless from a theoretical point of view, whether these last were placed on the out-bye or in-bye end of the airway, it was found more convenient to install them on the in-bye side, and that rule has always been followed.

As soon as the miners had left, the timber-men prepared the doors and brattices required to increase the circulation of the air in the airway, and when the observers arrived at 8 p.m., all was ready to commence operations.

While one observer ascertained the tightness of the pipes and apparatus,* adjusted the zero of the water-gauge, and recorded the atmospheric observations; a second observer immediately commenced with his assistants to measure the length of the airway and to obtain at intervals of about 30 feet, the perimeter and area of the gallery.

These preliminaries being finished, the four anemometers were placed at four points of the area of measurement, and at a given signal they were started simultaneously with a seconds' counter. Without delay, ten consecutive readings of the loss of pressure were taken at intervals of ¼ minute, at the end of which the anemometers and counter were stopped.

This operation was twice repeated, sometimes three times, and in one particular experiment, six times; after which the general testings under the conditions above indicated were made.

The same operations were always carried out by the same persons, with the same instruments, and all the readings were checked by a second observer.

Afterwards, every experiment afforded data for a long series of calculations, which are recorded in the table accompanying this paper.† One of

* Perfect tightness was only attained, especially at first, after many hours of patient labour. † Appendix A.

these calculations was very complicated, that necessary for determining the mean velocity of the air. The simple arithmetical mean of the velocities observed appeared insufficient as an approximation, and the solid cylindro-conic, defined by the curves of equal velocity, was determined; the volume of that solid was evidently equal to the volume of air, and dividing it by the area of the testing station, the geometrical mean velocity was obtained with all possible accuracy.*

In spite of the care taken in the observations, a cause of error brought to light in 1877 by the Gard Ventilation Commission, and since verified by the Prussian Fire-damp Commission, could not be avoided: that the vane anemometers, corrected for the experiments, gave exaggerated values of the actual velocities. One must, perforce, admit that for a like relative velocity an anemometer turns more quickly when it receives motionless the shock of air than when it moves at the end of the wand of a testing-machine. But this is not the place to discuss this singular paradox; it is sufficient to state that the exaggeration, increasing with the rapidity of the air may reach 10 per cent., with velocities of 1,200 feet per minute.

In order to avoid this error, the anemometer should be adjusted by means of a volumetric apparatus, a gas-meter for instance, as done by Mr. Althans of Breslau; but this method was not available. As the great majority of air-measurements are made daily in mines with anemometers corrected by the rotary testing-machine, it seemed desirable to rely upon the same system of correction, even if incorrect, as it would permit of comparisons being made, and facilitate the application of the numerical coefficients deduced from these experiments.

Before giving the results of the experiments, it is the writer's duty to express his gratitude to the gentlemen whose generous assistance has ensured success; in the first place to the directors of the Bessèges Colliery Company, who have most willingly paid the necessary expenses, and to the assistants whose zeal never flagged, in spite of the particularly disagreeable physical conditions under which the experiments were made, Mr. F. Dubost, mining engineer, Mr. S. Moulin, surveyor, and his assistant Mr. Gaston Agniel, Jun.† He must also address his thanks to Mr. M.

* Appendix D.

† Although the number of experiments was only twelve, fifteen meetings were required to complete them. The first experiment was repeated because it was spoilt by a serious error, owing, no doubt, to the unskilfulness of a first attempt; the second, because it was believed to be erroneous, although it was perfectly correct; finally, a trial, in which the distribution of velocities appeared to be abnormal had to be made a second time. The fifteen meetings occupied the month of November and the commencement of December, being made at the rate of three per week.

Walton Brown and Mr. R. A. S. Redmayne, for carefully transforming the results of the experiments, and for revising the formulæ and the calculations of the various values of the coefficient of friction in accordance with English standards of weights and measures.

3.—Of the Ratio of the Loss of Pressure to the Square of the Mean Velocity.

In giving the formula of the loss of pressure in the galleries of a mine—

$$h = k\frac{\mathrm{L}pv^2\delta}{s\delta_0},$$

all the laws of proportion which it implies have been accepted without question. Nevertheless one of these allowed a serious doubt to exist, viz., that which makes the loss of pressure increase proportionally to the square of the mean velocity of the air.

It is known that most authorities who have studied the laws of the flow of fluids in channels of various kinds have recognized that this ratio ceased to be exact for small velocities, and have been led to introduce into the formula of the loss of pressure, say a term of the first degree (Coulomb, de Prony, d'Aubuisson, Darcy, Arson, . . .) :—

$$h = av + bv^2,$$

or an index less than 2 (de Saint-Venant, Régnolds, Flamant) :—

$$h = cv^x.$$

On the other hand Mr. Rateau, professor at the Saint-Etienne School of Mines, has recorded an experiment made at the Montrambert collieries,* not on a length of gallery, but on the whole mine, where the generating pressure of the ventilation appeared to increase as the 1·75th power of the volume.

It was important therefore, at the outset, to be satisfied on this subject, and for that purpose in two of the experiments observations of the loss of pressure were increased by varying each time the value of the mean velocity.

The first of these experiments (No. 10 in the table) was made in a rolleyway, propped with oak timber; the frames, consisting of a crowntree and two props, were placed at an average distance of about 3 feet (0·90 metre), centre and centre, and the intervals between the frames and the sides filled with round poles. The mean height under the crowntrees was 6·1 feet (1·85 metres), the width 3·9 feet (1·20 metres) at the top, and about 6·9 feet (2·10 metres) at the bottom. This gallery was very old, and by reason of the successive repairs, its section presented considerable irregularities, a circumstance favourable however to the

* *Bulletin de la Société de l'Industrie Minérale*, series 3, vol. vi., page 133.

production of a heavy loss of pressure. The road, slightly sinuous but generally straight, was 318·5 feet (97·08 metres) long.

It was near the Créal fan, which allowed of the production of considerable air-velocities. A separation-door, which could be opened gradually, afforded an easy means of increasing the velocities from zero to the maximum.

The observations, six in number, are reproduced in the following table, in which the loss of pressure, proportional to the square of the mean velocity, is shown, calculated by the formula—

$$h = cv^2,$$

in which c is the mean result given in the last four experiments :—

No. of Experiment.	Mean Velocity per minute.		Loss of Pressure.		Differences.
	v.	v^2.	Observed.	Calculated.	
	Feet.		Inches.	Inches.	Inches.
1	182·3	33,233	0·0142	0·0126	− 0·0016
2	261·2	68,225	0·0276	0·0260	− 0·0016
3	423·8	179,606	0·0693	0·0681	− 0·0012
4	586·8	344,334	0·1315	0·1303	− 0·0012
5	719·4	517,536	0·1953	0·1961	+ 0·0008
6	827·2	684.256	0·2571	0·2591	+ 0·0020

The differences only amount to a few ten-thousandths of an inch more or less, and under these conditions it is permissible to assert that the rule is sufficiently accurate for general application.

But the precision of the results allows the question being followed more closely. It is easy, in fact, to recognize by the direction and amount of the differences that an influence, of the same nature as that observed by the authorities before quoted, exerts itself on the variations of the loss of pressure. If the simple formula of Flamant be accepted, an attentive study of the observations leads one to replace the square of the velocity by the 1·9267th power*—

$$h = cv^{1·9267}.$$

The differences then sensibly diminish as shown by the following table :—

No. of Experiment.	Loss of Pressure.		Differences.
	Observed.	Calculated.	
	Inches.	Inches.	Inches.
1	0·0142	0·0138	− 0·0004
2	0·0276	0·0279	+ 0 0003
3	0·0693	0·0705	+ 0·0012
4	0·1315	0·1323	+ 0·0008
5	0·1953	0·1957	+ 0·0004
6	0·2571	0·2563	− 0·0008

* Appendix E.

It may be remarked that these new results diverge little from the former, and do not invalidate in a material degree, at least as regards its application to mine ventilation, the law now under consideration.

The second experiment (No. 5 in the table) was made in a rolley-way, arched semi-circularly, 6·5 feet (2 metres) in height by 6·4 feet (1·95 metres) average width. The road was straight and 363·8 feet (110·90 metres) long. This gallery was a main return airway for the Créal colliery, and air-velocities could be produced of 1,000 to 1,200 feet per minute (5 to 6 metres per second), the strongest observed in the course of the experiments. Nevertheless, the loss of pressure was minimized owing to the regularity of the sides, at the same time being lubricated by the greasy covering which the return-air deposits upon everything situated in its course. And in this instance also, by means of a door gradually opened, four observations were made, as shown in detail in the following table :—

No. of Experiment.	Mean Velocity per minute.		Loss of Pressure.		Differences.
	v	v^2	Observed.	Calculated.	
	Feet.	Feet.	Inches.	Inches.	Inches.
1	466·1	217,249	0·0146	0·0150	+ 0·0004
2	693·3	481,664	0·0331	0·0331	0·0000
3	861·2	741,655	0·0508	0·0512	+ 0·0004
4	1030·7	1,062,342	0·0736	0·0732	– 0·0004

In the above table, the proportion of the loss of pressure to the square of the velocity is proved without the slightest doubt.

Clearly one could not affirm, by reason of the small value of the losses of pressure observed, and their insufficient number, that an influence in the same direction and of the same nature does not exist as that revealed by the first experiment. But that is immaterial, and for the practical purposes of this paper the harmonious results of the two experiments authorize the assertion that the law of the ratio to the square of the velocity is exact enough to serve as a sound basis for the calculation of the loss of pressure in underground galleries.

These first results were of a nature to inspire one with great confidence as to the accuracy of the means of observation. They give in advance a real guarantee of the numerical values which are to be deduced as the result of the experiments for the determination of the coefficient of the loss of pressure k.

As already mentioned, the experiments will be divided into three

groups, according to the nature of the sides of the galleries in which they were made, and they will be reviewed in the following order:— Unsupported sides, arched and timbered galleries.

4.—Galleries with Unsupported Sides.

Experiment No. 1.—The first experiment was made in a cross-measures stone-drift, at the first level of the Créal colliery, having the usual dimensions of the haulage roads—viz., a height on the rail of from 6·2 to 6·5 feet (1·90 to 2 metres), and an equal width. This will in future be termed the normal gallery. The road was quite straight and 308 feet (93·87 metres) long. The section was fairly regular, but some stone detached from the roof had left the top in a somewhat uneven condition (Fig. 7, Plate V.).

The principal data and the results of this experiment are grouped together in the following table. The observations of the mean velocity and of the loss of pressure are two in number, as is the case in all the following experiments. The weight of a cubic foot of air has been adopted in all cases for the calculation of the coefficient of friction at the uniform rate of 0·0750 pound (1·200 kilogrammes):—

Length of airway	308 feet.	93·87 metres.
Mean area	38·6 square feet.	3·584 square metres.
„ perimeter	24·3 feet.	7·40 metres.
Weight of a cubic metre of air ...	—	1·183 kilogrammes.
„ cubic foot „ ...	0·0738 pound.	—
Observations—	A.	B.
Mean velocity, per second ...	2·300 metres.	2·284 metres.
„ „ per minute ...	452·7 feet.	449·6 feet.
Loss of pressure	0·93 millimetre.	0·91 millimetre.
„ „	0·0366 inch.	0·0358 inch.
k	0·00094	0·00093
Mean value of k ...	0·00093.	

The velocity was rather small, and consequently the loss of pressure was equally unimportant.

Experiment No. 2.—A normal cross-measures drift in the fourth level of the Créal colliery was chosen, the mean area, however, being slightly larger—viz., 44·5 square feet (4·13 square metres) in place of 38·6 square feet (3·584 square metres), (Fig. 8, Plate V.).

This cross-measures drift, which was perfectly straight, had been driven through a very compact sandstone, by means of compressed-air drills. The figure shows the square form of roof, whereas the galleries driven by hand are always moré or less semi-circular or oval in shape.

Although the area was not absolutely constant, the sides were very regular, and did not present any serious inequalities.

The difficulty mentioned previously was experienced in this instance; it was impossible to obtain a mean velocity exceeding 400 feet per minute, and as the airway was not very long (250·5 feet), the loss of pressure barely exceeded 0·02 inch (½ millimetre). Nevertheless, owing to the delicacy of the instruments, the results of this trial merit the same confidence as those obtained elsewhere.

Length of airway...	250·5 feet.	76·35 metres.
Mean area...	44·5 square feet.	4·13 square metres.
„ perimeter	26·3 feet.	8·02 metres.
Weight of a cubic metre of air...	—	1·245 kilogrammes.
„ cubic foot „ ...	0·0777 pound.	—
Observations—	A.	B.
Mean velocity, per second ...	2·038 metres.	2·086 metres.
„ „ per minute...	401·2 feet.	410·6 feet.
Loss of pressure	0·56 millimetre.	0·57 millimetre.
„ „	0·0220 inch.	0·2244 inch.
k	0·00089	0·00086
Mean value of k ...	0·00087.	

The slight diminution in the value of the coefficient of the loss of pressure can only be explained by the greater regularity of the top of the drift. An examination of the curves of equal velocity shows that the loss of speed against the sides is sensibly less than in the preceding experiment.*

Experiment No. 3.—This experiment was made in the fourth level of the Bességes collieries, in a splendid cross-measures drift, absolutely straight, from 10 to 10½ feet (3 to 3·20 metres) in width and 6½ feet (2 metres) high. The mean velocity was 472 feet per minute (2·4 metres per second) which was not anticipated on account of the area of the section and the remoteness of the ventilator (Fig. 9, Plate V.).

Length of airway	810·7 feet.	94·70 metres.
Mean area	62·6 square feet.	5·816 square metres.
„ perimeter	32·1 feet.	9·77 metres.
Weight of a cubic metre of air...	—	1·265 kilogrammes.
„ cubic foot „ ...	0·0789 pound.	—
Observations—	A.	B.
Mean velocity, per second...	2·425 metres.	2·248 metres.
„ „ per minute	477·4 feet.	442·5 feet.
Loss of pressure	1·03 millimetres.	0·89 millimetre.
„ „	0·0406 inch.	0·0350 inch.
k	0·00104	0·00105
Mean value of k ...	0·00105.	

* Appendix F.

This relatively high result was a surprise. From preconceived ideas based upon the observations of numerous authorities, it was thought that the loss of pressure diminished more quickly in passing from one gallery to another of larger size, than the ratio of the perimeter to the area, or, in other words, that the value of the coefficient k would diminish with increased areas. The inverse result was obtained without the cause being understood. It may be admitted that the dentations produced at the roof by the alternations of hard and soft inclined strata possessed a relatively greater importance in large galleries. But that explanation alone is insufficient. The true cause appears to be indicated by the diagram of the curved lines of equal velocity, where it appears that the maximum velocity, instead of occupying, as is usual, the centre of the gallery, is thrown against the right side.* This caused an increase of the friction, which resulted in an increased value of the coefficient k.

However, the increase was not very great, and cannot be considered as striking a discordant note in the results.

Experiment No. 4.—The fourth and last experiment on the galleries with unsupported sides was made on a type of the gallery of small area. The model chosen being a rising gallery, 5·6 feet (1·70 metres) in height by 3·9 feet (1·20 metres) of mean width, connecting the first with the second level of the Bessèges collieries, and used as a travelling road for the Créal colliery workmen. The inclination was 40 per 100, and steps of oak wood fixed on the floor assisted the ascent. The general direction was straight, but it was rather crooked in parts. The section, about 22 square feet (2 square metres), was regular, but as the gallery had been driven at a very steep gradient it had a very irregular outline, as shown in Fig. 10, Plate V. This circumstance, added to the projection of the steps fixed on the floor, prepared the observers for a sensible increase of the coefficient of the loss of pressure which was confirmed by the experiments. High velocities of the air were easily obtained, but this is a much more easy problem with galleries of small area than with larger airways.

Length of airway	246·7 feet.	75·20 metres.
Mean area	21·8 square feet.	2·022 square metres.
„ perimeter	17·7 feet.	5·39 metres.
Weight of a cubic metre of air ...	—	1·201 kilogrammes.
„ cubic foot „ ...	0·0750 pound.	—

* Some yards from the out-bye end of the airway the current of air was diverted at right-angles to the right, in order to enter the Saint-Emile seam and pass to the ventilator. Probably this lateral pull caused the high velocities to press against the right side.

Observations—	A.	B.
Mean velocity, per second ...	4·173 metres.	4·309 metres.
„ „ per minute ...	821·5 feet.	848·2 feet.
Loss of pressure	4·24 millimetres.	4·56 millimetres.
„ „	0·1669 inch.	0·1795 inch.
k	0·00122	0·00124
Mean value of k ...	0·00123.	

After the previous remarks, the decided increase of the coefficient of the loss of pressure in this case was not a surprise. Nevertheless, it was not thought that the inequalities and ruggedness of the airway were the only causes. Although experiment No. 3 may not have confirmed the author's opinion, he still thinks that all other things being equal, the coefficient of the loss of pressure varies but slightly with the area of the galleries under observation, diminishing for large openings, and increasing for narrow passages. The diminution may be inappreciable when passing from a normal to a large gallery; the increase may, on the contrary, assume important dimensions when the area decreases. It will be seen that the next experiment confirmed this assumption.

It is, however, entirely in accordance with the conclusions adopted by the authorities whose names have been quoted. In consequence of his own well-known experiments on the flow of air and illuminating gas in pipes, Mr. Arson has developed the binomial formula:—

$$h = \frac{L\delta}{D}(av + bv^2),$$

in which the values of the coefficients a and b increase as the diameters diminish. Mr. Devillez adheres to a single term and a constant coefficient:—

$$h = \frac{kL\delta v^2}{D^{1\cdot 273}},$$

but he affects the diameter, a simple function of the perimeter, by an exponent higher than unity, which is the same as giving to the perimeter a greater influence than that of simple inverse proportion.

It would be surprising if it were not the same for mine galleries.

Recapitulation.—The first three experiments have given very concordant results which warrant their mean value being taken as the practical value of the coefficient of the loss of pressure, in straight galleries with unsupported sides, whether normal or large. This mean value is equal to—

$$k = 0\cdot 00095.$$

For galleries of small area, there is but one observation,

$$k = 0\cdot 00123,$$

which may be applied to galleries analogous to the one on which the experiment was made.

Not being able to multiply the experiments sufficiently to provide for all cases, the mining engineer who makes use of these numerical values must judge to what extent he should increase or diminish them, in order to allow for the curvature of the galleries and the ruggedness of their sides.

5.—Galleries Lined with Masonry.

The normal arched gallery of the Bessèges collieries is 6·5 feet (2 metres) wide, by 6·5 feet (2 metres) high under the crown; its outline consists of two vertical side-walls, surmounted by a semi-circular arch (Fig. 11, Plate VI.).

Experiment No. 5.—The airway selected for the present experiment has already been described, being the one used to verify the ratio of the loss of pressure to the square of the mean velocity. Its direction was straight, and its sides were regular, although at certain points they have given a little from rock-pressure; they are covered with the moist and greasy coating, common to the return airways of most mines.

The proximity of the ventilator enabled high velocities to be produced in the gallery, without which the loss of pressure would have been barely apparent.

Length of airway	363·8 feet.	110·90 metres.
Mean area	37·1 square feet.	3·4470 square metres.
„ perimeter	23·0 feet.	7·02 metres.
Weight of a cubic metre of air	—	1·184 kilogrammes.
„ cubic foot „	0·0739 pound.	—
Observations—	A.	B.
Mean velocity, per second...	5·236 metres.	4·375 metres.
„ „ per minute	1030·8 feet.	861·2 feet.
Loss of pressure	1·87 millimetres.	1·29 millimetres.
„ „	0·0736 inch.	0·0508 inch.
k	0·00031	0·00030
Mean value of k ...	0·00030	

This value is full of interest; it shows that the immediate effect of the walling of the galleries with unsupported sides is to reduce the loss of pressure to less than one-third of its original amount. It will be observed that this gain increases further when masonry arches are substituted for timbering in galleries.

The importance of this first result led to its being checked by another observation, made in another gallery of the same area and similar nature. The seventh level of the Oréal colliery afforded an airway answering precisely to this description, and of an exceptional length.

Experiment No. 6.—It was not possible to obtain high velocities of air in this gallery, but sufficient compensation was found in the great length of the airway which measured 1,084·9 feet (330·66 metres).

This airway was quite straight and of a perfectly regular outline. The air coming direct from the surface by the Brissac shaft was not yet contaminated by underground exhalations, and had allowed the sides to retain their original aspect and roughness.

The pipes being of insufficient length for so long an airway, use was made of a compressed air-pipe placed in the gallery, and of which, for the moment, a portion was isolated.

Length of airway	1084·9 feet.	330·66 metres.
Mean area	38·8 square feet.	3·6080 square metres.
„ perimeter...	23·6 feet.	7·18 metres.
Weight of a cubic metre of air	—	1·221 kilogrammes.
„ cubic foot „	0·0762 pound.	—
Observations—	A.	B.
Mean velocity, per second...	1·963 metres.	1·950 metres.
„ „ per minute	386·4 feet.	383·8 feet.
Loss of pressure	0·94 millimetre.	0·93 millimetre.
„ „	0·0370 inch.	0·0366 inch.
k	0·00037	0·00037
Mean value of k ...	0·00037	

The coefficient of the loss of pressure here presents a considerable increase, difficult to explain.

May it perhaps be attributable to the fact that the sides, moist and greasy in the preceding experiment, were here dry and rough. Perhaps again the flanges of the compressed air-pipes gave rise to an appreciable increase of friction. Be that as it may, the two values just obtained (0·00030 and 0·00037) may be considered to be the extreme limits of the coefficient of the loss of pressure in arched galleries, normal and straight, and the author proposes that their mean (0·00033) shall be taken as the numerical value for calculations.

Experiment No. 7.—It was not possible, to the author's great regret, to make an experiment in arched galleries of large area. Although that type of gallery is frequently met with in the Bessèges collieries it only exists in lengths too short to produce an appreciable loss of pressure.

Before passing to the galleries of small dimensions, it appeared to be useful to make an observation in a normal gallery, which presented the interesting peculiarity of describing a long continuous curve, almost a semi-circle, as shown in Fig. 13, Plate VI.

The projection of the current of air against the concave side should produce an increase of friction, and consequently an increase of the coefficient of the loss of pressure, of which it was not without interest to know the measure.*

This gallery, situated on the second level of the Créal colliery, is a continuation with an interval of 750 feet, of the straight gallery used in experiment No. 5. The section is similar and quite as regular, but the velocity of the air is less, and the sides are more even (Fig. 14, Plate VI.).

Length of airway	335 feet.	102·12 metres.
Mean area	37·2 square feet.	3·4560 square metres.
„ perimeter...	23·0 feet.	7·02 metres.
Weight of a cubic metre of air	—	1·177 kilogrammes.
„ cubic foot „	0·0735 pound.	—
Observations—	A.	B.
Mean velocity, per second...	3·404 metres.	3·075 metres.
„ „ per minute	670·1 feet.	605·3 feet.
Loss of pressure	1·46 millimetres.	1·18 millimetres.
„ „	0·0575 inch.	0·0465 inch.
k	0·00063	0·00062
Mean value of k ...	0·00062	

The arched straight galleries have given on an average a value of 0·00033, and the unbroken curve had the effect of doubling, or nearly so, the coefficient of the loss of pressure.†

Experiment No. 8.—In the absence of arched galleries of large size, experiments were made on two different sizes of galleries of small area, one being 5·6 feet (1·70 metres) wide, and the other 3·9 feet (1·20 metres).

The former of these galleries was driven at the Bessèges colliery first level at a steep gradient, and its course was very sinuous, although deviating but little from a straight line (Fig. 15, Plate VI.). The section was very regular, being 5·6 feet (1·70 metres) wide between the side walls, and about 5·9 feet (1·80 metres) high under the crown (Fig. 16, Plate VI.).

* The acceleration of the velocities against the concave side is not shown very clearly by the curve-lines of equal velocity of this experiment, the place of air-measurement having been placed in the straight portion preceding the curve.

† The repetition, after some days' interval of this experiment, made at the beginning of the operations, and which was at first believed to be erroneous, contributed in a great measure to inspire confidence in the method of observation. The first time, the line of pipes in the airway had been inadvertently prolonged for 37 feet (12 metres) beyond the walled airway, in a part with unsupported sides, k had the value 0·00065; the second time, it ended correctly under the arch and the value was reduced to 0·00062.

Length of airway...	302·2 feet.	92·10 metres.
Mean area...	29·4 square feet.	2·7360 square metres.
„ perimeter	20·5 feet.	6·26 metres.
Weight of a cubic metre of air...	—	1·199 kilogrammes.
„ cubic foot „ ..	0·0749 pound.	—
Observations—	A.	B.
Mean velocity, per second...	2·950 metres.	3·111 metres.
„ „ per minute...	580·7 feet.	612·4 feet.
Loss of pressure	0·94 millimetre.	1·04 millimetres.
„ „	0·0370 inch.	0·0409 inch.
k	0·00052	0·00052
Mean value of k ...	0·00052.	

It was expected that the result would be intermediate between those given respectively by the arched straight galleries and by those continuously curved, and the observation fairly verified this opinion. However this result was not the mean of the other two; it was nearest to the higher, which encouraged the supposition that the diminution of the area began to exert the same sort of influence as that mentioned *a propos* of No 4 experiment, and which might be shortly designated the law of small areas. The next experiment confirmed this assumption very closely.

Experiment No. 9.—The second of the arched galleries of small section was also situated on the Bessèges colliery first level. It was only 3·9 feet (1·20 metres) wide by 6·2 feet (1·90 metres) high under the crown; it was used as a travelling road for the Créal colliery workmen. Like the preceding one, it was straight on the whole, but a little winding in parts. Air-velocities of from 800 to 1,000 feet per minute were readily produced, a circumstance which compensated for the shortness of the airway (Fig. 17, Plate VI.).

Length of airway...	201·1 feet.	61·30 metres.
Mean area...	22·9 square feet.	2·1250 square metres
„ perimeter	18·6 feet.	5·67 metres.
Weight of a cubic metre of air...	—	1·199 kilogrammes.
„ cubic foot „ ...	0·0749 pound.	—
Observations—	A.	B.
Mean velocity, per second...	4·535 metres.	4·569 metres.
„ „ per minute...	892·7 feet.	899·4 feet.
Loss of pressure	1·82 millimetres.	1·88 millimetres.
„ „	0·0716 inch.	0·0740 inch.
k	0·00055	0·00055
Mean value of k ...	0·00055.	

The magnitude of the area excepted, this gallery is altogether comparable to the preceding one: the same windings, the same outline, and the same kind of sides. It would be difficult to explain the rather serious

increase of the coefficient of the loss of pressure, if the law of small areas previously referred to be not accepted, according to which the co-efficient should increase as the section diminishes. In any case it may be considered that the result just obtained materially supports this law.

Conclusions.—The somewhat different values given by experiments Nos. 5 and 6 for the coefficient of the loss of pressure in arched galleries, normal and straight, conduce to the adoption of their mean, 0·00033, for practical calculations.

If the normal arched gallery ceasing to be straight presents a continuous curve in the same direction, the coefficient of the loss of pressure may rise to 0·00062.

If it be simply winding the increase stops at 0·00052, but may rise to 0·00055 in galleries of small area.

Such is the group of results given by galleries lined with masonry. It had been hoped that a more regular and complete scale would have been obtained ; but it is rare to find in mines types of galleries perfectly regular and similar, answering at the same time to the numerous exigencies of the method of observation. With the best will in the world, it has been found impossible to make further experiments.

6.—Galleries propped with Timber.

Experiment No. 10.—The timbering used in the Bessèges collieries consists of three pieces :—A crowntree and two props put together in the form of a trapezium, taking care, when the timber is curved, to turn the concave side inwards. Their distance apart from centre to centre varies from 3·9 feet (1·20 metres) to 4·3 feet (1·30 metres), the space between them and between the roof and sides being stowed with small poles.

The average section of a timbered gallery should, ordinarily, be a mean between the areas inside the timbering and between the gears, but this would lead to complicated calculations and would not give definite results. It seemed preferable to measure the areas and perimeters within the timbering, and to treat the excess of area, in the intervals between, as simple irregularities.*

The gallery used in No. 10 experiment was an ordinary normal rolley-way timbered with oak, the average height being 6·1 feet (1·85 metres) under the crowntrees, 3·9 feet (1·20 metres) wide at the top, and 6·9 feet

* To be accurate, the sectional area should be increased by the empty spaces between the backing-poles and the sides. But as the air-velocity is here necessarily very slack, it appeared that without inconvenience this complication could be avoided. Where the air measurements were taken, the interstices were stuffed with hay so as to measure the entire air-volume.

(2·10 metres) at the bottom inside the props. Being very conveniently situated at the point of entrance of the second level of the Créal colliery and close to the fan, it allowed of the verification under favourable circumstances of the law that the ventilating pressure varies as the square of the velocity, an experiment already described (Fig. 18, Plate VI.).

As already mentioned, this gallery, being old, had been frequently repaired and was therefore somewhat irregular in outline. The gears, old and new, succeeded one another at close intervals with considerable differences in height and form, but affording sufficient room for the passage of horses and trains of wagons. The course is straight with the inevitable sinuosities of a gallery driven in the seam and not set out by marks.

Length of airway	318·5 feet.	97·08 metres.
Mean area	32·7 square feet.	3·0370 square metres.
„ perimeter	22·7 feet.	6·91 metres.
Weight of a cubic metre of air ...	—	1·201 kilogrammes.
„ cubic foot „ ...	0·0750 pound.	—
Observations—	A.	B.
Mean velocity, per second ...	4·202 metres.	3·655 metres.
„ per minute ...	827·2 feet.	719·5 feet.
Loss of pressure	6·53 millimetres.	4·96 millimetres.
„ „	0·2571 inch.	0·1953 inch.
k	0·00169	0·00171
Mean value of k ...	0·00170.	

The coefficient of friction has here a very high value, higher than any hitherto observed. But in order to give authority to this important result, it was necessary to check it by a second experiment under similar conditions.

Experiment No. 11.—A newly repaired gallery in the St. Félix seam, in the second level of the Créal colliery, afforded an excellent example of a normal gallery, regularly and properly timbered. It was entirely isolated for the whole of its course from the rest of the workings, an unusual circumstance in a gallery of this kind. The mean dimensions inside the timber were, 6·4 feet (1·95 metres) high, 3·9 feet (1·20 metres) wide at the top, and 7·2 feet (2·20 metres) at the bottom. The pine timber was set 3·9 feet (1·20 metres) apart, on an average from centre to centre. In certain places, and in particular where the air-measurement was made, the crown-trees were at a considerable inclination following that of the roof of the seam (Fig. 19, Plate VI.).

As in the former gallery, the airway was straight with slight sinuosities. It was possible, though with difficulty, to produce a mean air-speed of 423 feet (2·15 metres) per minute, which gave here an appreciable loss of pressure, though it would not have done so in a gallery lined with masonry.

Length of airway	263·3 feet.	80·25 metres.
Mean area	35·9 square feet.	3·3370 square metres.
„ perimeter	23·7 feet.	7·23 metres.
Weight of a cubic metre of air ...	—	1·169 kilogrammes.
„ cubic foot „ ...	0·0730 pound.	—
Observations—	A.	B.
Mean velocity, per second ...	2·151 metres.	2·146 metres.
„ per minute ...	423·4 feet.	422·4 feet.
Loss of pressure	1·13 millimetres.	1·12 millimetres.
„ „	0·0445 inch.	0·0441 inch.
k	0·00147	0·00146
Mean value of k ...	$\underbrace{\qquad\qquad}_{0·00147.}$	

The diminution of the coefficient is easily explained by the greater regularity of the gallery.

Experiment No. 12.—Timbered galleries of large dimensions are rare at the Bessèges collieries, and are always very short, being only made at meetings and sidings. This experiment had to be omitted, but with less regret however, as experiments made in the arched galleries used as sewers and railway-tunnels could take its place.

Galleries of small section, timbered or not timbered, are on the other hand very common; they form the whole network of rolley-ways, characteristic of the system of working at the Bessèges collieries. Unfortunately these roads are seldom isolated from the neighbouring workings; they are lined with stowage, crossed by other roads, forked or joined together in such wise, that it was with difficulty that a road was found absolutely independent, regularly timbered, and sufficiently long for the purpose.

This airway lay between the third and fourth levels at the Créal colliery and was a part of the independent air-return from the seventh level, where on several occasions outbursts of fire-damp have taken place. It is driven in the Sainte Barbe seam with an average inclination of 30 per 100.

The timbering is set about 4 feet (1·20 metres) on an average apart, and the height beneath the crowntrees is 4·9 feet (1·50 metres), the width at the top being 3·6 feet (1·10 metres) and at the bottom 5·6 feet (1·70 metres). The airway is generally straight, but a little undulating in detail both in vertical and horizontal directions (Fig. 20, Plate VII.).

Length of airway	303·6 feet.	92·53 metres.
Mean area	22·4 square feet.	2·0850 square metres.
„ perimeter	18·9 feet.	5·77 metres.
Weight of a cubic metre of air...	—	1·200 kilogrammes.
„ cubic foot „ ...	0·0749 pound.	—

Observations—	A.	B.
Mean velocity, per second...	2·310 metres.	2·138 metres.
" " per minute...	454·7 feet.	420·9 feet.
Loss of pressure	3·32 millimetres.	2·71 millimetres.
" "	0·1307 inch.	0·1067 inch.
k	0·00247	0·00235
Mean value of k ...	0·00241.	

The value of the coefficient of friction shows here a considerable increase, difficult to explain. Without doubt, the curvatures in the airway were greater than in the preceding cases, and the surface irregularities between the props were relatively of greater importance. Nevertheless, it would be impossible to account for so large an increase except on the supposition that the small sectional area had its own influence upon the coefficient of friction about which we have already spoken several times.

From the results thus obtained, it would appear that this influence was of great importance in small timbered galleries.

Conclusions.—The two values for the coefficient of friction obtained in normal and straight timbered galleries represent the two extreme cases which are met with in practice—newly timbered drifts and old drifts frequently repaired. Their mean may therefore be safely adopted in calculations, viz.:—

$$k = 0{\cdot}00158.$$

This value augments very rapidly as the sectional area diminishes; in the only case of a timbered gallery of small dimensions which was tested, it reached 0·00241. It is necessary, however, to add that the air-course was somewhat crooked.

7.—General Summary and Conclusions.

Recapitulatory Table.—In order to show clearly the results of the twelve experiments, they are collected together in the following table:—

			Averages.
Unlined galleries—			
1.	Straight, normal area	0·00093	0·00095
2.	" " "	0·00087	
3.	" large area	0·00105	
4.	" small area		0·00123
Arched galleries—			
5.	Straight, normal area	0·00030	0·00033
6.	" " "	0·00037	
7.	Continuous curve, normal area ...		0·00062
8.	Sinuous, intermediate area... ...		0·00052
9.	" small area		0·00055
Timbered galleries—			
10.	Straight, normal area	0·00170	0·00158
11.	" " "	0·00147	
12.	Slightly sinuous, small area ...		0·00241

It will be observed that, in spite of individual differences, each group is confined within narrow limits, with large intervals in passing from one group to another. The three types of galleries are very plainly marked by the values of the coefficient of friction that they afford, and as might be expected they range themselves in the following order:—

1. Arched galleries, from	... ...	0·00030 to 0·00062
2. Unlined " "	... ...	0·00087 " 0·00123
3. Timbered " "	... ...	0·00147 " 0·00241

But, in addition to this first result of the experiments, an attentive examination of the table, incomplete though it may be, throws an interesting light upon the teaching alluded to from time to time in describing the results of the experiments. These observations may be briefly recapitulated while examining each in turn with regard to the influence of curves in the galleries, the sectional area, and the nature of the sides.

Effects of Curves.—The group of arched drifts is the only one sufficiently complete to admit of forming an opinion as to the effect of curves in the airway upon the rate of the loss of pressure. In the normal gallery the following interesting progression was observed:—

1. Arched drift, straight	... ...	0·00033
2. " " slightly sinuous ..	... ...	0·00052
3. " " continuous curvature	... ...	0·00062

It will be seen that the loss of pressure is practically doubled when the galleries are very crooked.

Effects of Area.—Only one experiment was made in galleries of large area, the sides being unsupported, and the air-course straight. The value of the coefficient of friction differed very little from that recorded for the normal gallery, under similar conditions; it has therefore been used in the estimation of the mean value to be used in calculations.

Observations have been made, in the case of galleries of small area, upon each of the three types; and each time they have given a very sensible increase in the value of the coefficient of friction, especially in timbered galleries, as may be seen from the following table:—

		Normal Area.	Small Area.
1. Arched galleries	... ...	0·00033	0·00055
2. Unlined "	... ...	0·00095	0·00123
3. Timbered "	... ...	0·00158	0·00241

It must not be forgotten that the small galleries were more unequal and more crooked than the normal galleries with which they are compared; nevertheless, the increase was so great and so regular as to

necessitate the interference of a new influence which has been described as the law of small areas. As already mentioned, many authorities have admitted that the coefficient of friction in air and gas pipes increases with small diameters; doubtless it will be the same in mine-galleries. This law may therefore be accepted provisionally in the vague terms here presented, until the time when many and accurate experiments shall have accurately determined its numerical conditions.

The mean value of the coefficient of friction proposed by Mr. Devillez for the whole of the galleries of a mine (k = 0·00180) appears to be an important confirmation of this law. The recapitulatory table shows that it has only been once exceeded in the case of timbered galleries of small area. It is too high for the average of all the galleries experimented upon.* But the galleries tested by Mr. Raux and his colleagues, had, in general, very small dimensions, the average area rarely exceeding 20 square feet (2 square metres), and decreasing often to 10 square feet (1 square metre). In such circumstances, the law cited above, combined with the variation in level of the galleries arranged in the closed circuit, very easily explains the high values proposed by Mr. Devillez.

In consequence of this law, mining engineers will be doubly interested in giving a large area to the airways, as by so doing, they will diminish the loss of pressure, first by decreasing the velocity, and secondly by the corresponding diminution of the value of the coefficient k.

Effects of the Sides.—In order to define with exactness the influence of the nature of the sides, it was necessary to confine the observations to normal straight galleries which are similar in all other respects, and have all been subjected to a double observation in different districts of the mine.

The following values have thus been obtained, regularly graduated and very characteristic:—

1. Arched galleries...	0·00033
2. Unlined "	0·00095
3. Timbered "	0·00158

From a comparison of these values, a rule of the greatest importance can be deduced, which may be defined in these words:—In the choice of supports, the engineer should not be guided entirely by considerations of

* The actual value of the coefficient obtained by Mr. Devillez was 0·00166; but in order to allow for the action of the natural ventilation occurring during the observations, which was not shown upon the water-gauge, he increased the value to 0·00180.

solidity or economy; he should also give attention to the influence which the support will have upon the air-current circulating in contact with it.

This axiom may be confirmed by a numerical example taken from daily practice in the working of mines.

It is becoming less and less frequent to have more than two small openings into a mine. The difficulty of access in mountainous districts, the presence of overlying water-bearing strata, or simply the desire to make use of old shafts already well fitted up and conveniently placed for the opening out of distant deposits, have often made the driving of long drifts necessary, which the air-current must traverse on its way from the surface to the workings, and from the workings to the surface. Numerous examples could be given, but without doing so, it will be admitted that it is not extravagant to assume a case where the air-current has to travel, either as an intake or return along a normal straight drift 1,312 feet long, with a mean area of 38·8 square feet.*

The volume circulating will be taken at 38,140 cubic feet per minute (18 cubic metres per second), which gives a mean velocity of 983 feet per minute. Therefore, in these circumstances, the ventilating pressures absorbed by this gallery will be equal to:—

	Inches.
1. Arched	0·253
2. Unlined	0·760
3. Timbered	1·275

Therefore, if the mine alone requires a ventilating pressure of 0·750 inches of water, the ventilating pressure that the ventilator, supposed to be an exhausting ventilator, must produce at the inlet will become in the

	Inches.
First case	1·003
Second case	1·510
Third case	2·025

Thus the motive power will vary in the ratio of 1 to 2, according as the 1,312 feet (400 metres) of main airway is lined with masonry or timbered.

But the question now being considered is of sufficient importance to be studied in all its aspects. Instead of a constant volume, let a constant

* This mean value of 38·8 square feet represents fairly well the average section of an ordinary rolleyway, arched or unsupported. It is perhaps a little larger than an ordinary timbered drift. The following values may be accepted for the perimeters:—Arched, 23·5 feet (7·17 metres); unsupported, 24·5 feet (7·45 metres); and timbered, 24·7 feet (7·52 metres). The weight of a cubic foot of air is taken as equal to 0·0750 pound, as in all the preceding experiments.

ventilating pressure be taken, and consider for example how the volume will vary with the three kinds of rubbing surfaces, assuming that the ventilator, running at its usual speed, produces in the upcast shaft a depression of 1·575 inches (40 millimetres) of water.

It is impossible to calculate *a priori* the ventilating pressure required for any mine, as the workings present a network of excavations much too complicated for analysis, with interlacing drifts, empty spaces left in the goaves, the irregular shapes of the working-faces and stowage, and above all, the incessant changes due to the daily progress of the workings. In order to overcome this difficulty, the writer proposed, in 1872, the method *a posteriori* of the equivalent orifice, which has had the good fortune to have met with the most favourable reception from mining engineers.

This method consists in substituting, for the mine under consideration, the orifice in a thin plate requiring the same pressure to pass through it the same volume of air, which orifice therefore offers the same resistance as the mine, and is equivalent to it.

The area of this orifice is obtained from the following formula, when the pressure h and the volume V are known:—

$$a = \frac{0{\cdot}38\,V}{\sqrt{h}}.*$$

In the particular case now being considered, it may be supposed that the mine alone, without the gallery of 1,312 feet (400 metres) which serves as its intake or return, is equivalent to an orifice of 16·15 square feet (1·50 square metres). The required ventilating pressure obtained from the above formula is:—

$$h = \frac{0{\cdot}38^2\,V^2}{16{\cdot}15^2} = 0{\cdot}000553\,V^2.$$

On the other hand, the 1,312 feet (400 metres) of gallery require

$$h = k\,\frac{1{,}312\,pv^2\,\delta}{s\,\delta_0},$$

a formula which becomes, by substituting volume by area, *i.e.*, $\frac{V}{s}$ for the mean velocity v, and admitting $\delta = \delta_0$:

$$h = k\,\frac{1{,}312\,p\,V^2}{s^3}.$$

* This formula is deduced from that relating to the volume that will pass through an orifice in a thin plate—

$$V = Ka\sqrt{\frac{2g\,ho}{12.\delta}}$$

assuming that the coefficient for the *vena contracta* K = 0·65 and that the weight of a cubic foot of air is 0·0750 pound.

The sum of these two formulæ must equal the total depression produced by the ventilator, *i.e.*, 1·575 inches (40 millimetres) of water:

$$0{\cdot}000553\,V^2 + k\,\frac{1{,}312\,p\,V^2}{s^3} = 1{\cdot}575,$$

from which the value of the volume can be deduced:

$$V^2 = \frac{1{\cdot}575}{0{\cdot}000553 + \frac{k\,1{,}312\,p}{s^3}},$$

s is equal to 38·8 square feet (3·60 square metres); and p is also known.* It is only necessary, therefore, to substitute for the coefficient of friction k, its successive values corresponding to the three kinds of supports to be able to calculate in each case the volume produced per minute V.

Consequently according to the supports used the volume will be :—

	Cubic Feet per Minute.
Arched gallery	46,006
Unlined "	38,258
Timbered "	32,835

These results are beyond question. They show with sufficient exactness, the two points desired to be established, namely, the disastrous influence of timbered galleries on the ventilation and the great advantage of masonry linings for airways.

Perhaps a further improvement might be accomplished by coating the surface, always rather rough, of the arching, and it is possible that even the gain thus obtained would justify the expense. The author regrets that he has not been able to verify this interesting supposition.

Graphic Representation.—It is possible to show very clearly in one diagram the influence of the three kinds of lining (Fig. 21, Plate VII.).

Taking, as the starting point, the profile of the stone-drift, without lining, from experiment No. 2, the profile of the arched drift, and that of the timbered drift, requiring for the same volume the same ventilating pressure, have been drawn upon it. The contour-lines surround one another and increase from the contour-line of the arched drift to that of the timbered drift; so that the decrease in velocity may compensate for the increase in the value of the coefficient of friction.

It will be noticed that there is a space all round, or almost all round, between the arched and unlined drifts sufficient for the insertion of 9 inches of brickwork, from which circumstance it becomes evident that it is possible to line a drift, without enlarging it, without any detriment to the ventilation.

* The values of p have been given in a preceding note.

The space within the timber, in the timbered gallery, considerably exceeds the area of the original unlined drift. It follows, therefore, that, if one wishes to timber an unlined drift without loss of ventilating pressure, it will be first necessary to, at least, double its original area.

CONCLUSION.

In concluding this paper, the author must admit that his experiments are only in accordance with what simple reflection would have led him to foresee. He thinks nevertheless that it is worth while to substitute exact numbers for general statements. It is the clearly understood duty and interest of the manager of a fiery mine to increase the ventilating current as far as possible; and this will be more certainly attained by endeavouring to reduce the loss of pressure or water-gauge wherever it has excessive values, rather than by turning his attention to the search for an improved ventilator. In addition to the well-known and excellent remedy, viz., the enlargement of the galleries and consequent reductions of velocities, these experiments have brought other causes to light which should not be neglected, viz., the substitution of masonry linings for timber, and even for the naked sides of the drifts; the straightening of the drifts; and the enlargement of small galleries which are not only detrimental to ventilation from the increase in the velocity of the air-current, but also cause an appreciable increase in the value of the coefficient of friction.

The author trusts that he has performed a useful duty. Such was his desire when he commenced this study, and he will be content if he has succeeded in his attempt.

EXPLANATION OF PLATES.

EXPERIMENT No. 1, FIG. 7, PLATE V.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No	Feet per Minute.	Metres per Second.
1	352	1·787	13	570	2·897
2	376	1·911	14	221	1·122
3	389	1·975	15	346	1·757
4	339	1·724	16	537	2·728
5	321	1·631	17	533	2·706
6	472	2·397	18	526	2·673
7	519	2·635	19	145	0·735
8	575	2·922	20	370	1·880
9	344	1·749	21	395	2·006
10	357	1·815	22	396	2·011
11	503	2·553	23	390	1·983
12	583	2·960	24	215	1·090

Mean velocity, per second ... ... 2·168 metres.
„ „ per minute ... ... 427 feet.
Mean area of the place of air measurement... ... 3·7045 square metres.
„ „ „ „ ... ... 38·6 square feet.
Volume of air, per second ... ... 8·031 cubic metres.
„ „ per minute ... ... 17,017 cubic feet.
Maximum velocity, per second... ... ... 3·040 metres.
„ „ per minute ... ... 598 feet.
Ratio of maximum to mean velocity ... ... 1·402

EXPERIMENT No. 2, FIG. 8, PLATE V.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No.	Feet per Minute.	Metres per Second.
1	407	2·065	13	541	2·749
2	483	2·455	14	499	2·534
3	481	2·446	15	410	2·084
4	248	1·262	16	506	2·569
5	441	2·240	17	493	2·504
6	516	2·621	18	478	2·426
7	545	2·768	19	456	2·319
8	529	2·689	20	385	1·957
9	297	1·509	21	437	2·219
10	470	2·388	22	450	2·285
11	545	2·770	23	385	1·957
12	583	2·962	24	436	2·213

Mean velocity, per second ... ... 2·377 metres.
„ „ per minute ... ... 468 feet.
Mean area of the place of air measurement ... ... 3·5683 square metres.
„ „ „ „ ... ... 38·4 square feet.
Volume of air, per second ... ... 8·482 cubic metres.
„ „ per minute ... ... 17,973 cubic feet.
Maximum velocity, per second ... ... 2·970 metres.
„ „ per minute ... ... 585 feet.
Ratio of maximum to mean velocity ... ... 1·249

EXPERIMENT NO. 3, FIG. 9, PLATE V.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No.	Feet per Minute.	Metres per Second.
1	368	1·869	15	623	3·165
2	295	1·497	16	420	2·132
3	414	2·102	17	434	2·207
4	477	2·422	18	514	2·609
5	397	2·018	19	541	2·749
6	452	2·295	20	603	3·061
7	421	2·138	21	586	2·978
8	588	2·988	22	480	2·437
9	643	3·266	23	257	1·307
10	393	1·994	24	397	2·016
11	484	2·461	25	494	2·511
12	475	2·413	26	490	2·487
13	457	2·323	27	437	2·221
14	568	2·884	28	412	2·092

Mean velocity, per second	2·401 metres.
„ „ per minute	473 feet.
Mean area of the place of air measurement	5·8821 square metres.
„ „ „ „	63·3 square feet.
Volume of air, per second	14·123 cubic metres.
„ „ per minute	29,926 cubic feet.
Maximum velocity, per second	3·340 metres.
„ „ per minute	657 feet.
Ratio of maximum to mean velocity	1·391

EXPERIMENT NO. 4, FIG. 10, PLATE V.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No.	Feet per Minute.	Metres per Second.
1	637	3·234	11	1,035	5·259
2	741	3·763	12	819	4·160
3	255	1·295	13	821	4·171
4	829	4·213	14	988	5·019
5	950	4·826	15	1,013	5·145
6	902	4·581	16	718	3·647
7	665	3·380	17	563	2·862
8	655	3·329	18	944	4·797
9	873	4·436	19	972	4·937
10	1,095	5·565	20	511	2·598

Mean velocity, per second	4·136 metres.
„ „ per minute	814 feet.
Mean area of the place of air measurement	2·1032 square metres.
„ „ „ „	22·6 square feet.
Volume of air, per second	8·699 cubic metres.
„ „ per minute	18,433 cubic feet.
Maximum velocity, per second	5·640 metres.
„ „ per minute	1,110 feet.
Ratio of maximum to mean velocity...	1·364

EXPERIMENT No. 5, FIG. 11, PLATE VI.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No.	Feet per Minute.	Metres per Second.
1	783	3·980	13	1,239	6·293
2	1,036	5·260	[illegible]	1,045	5·307
3	1,025	5·205	15	937	[illegible]
4	881	4·476	16	1,159	[illegible]
5	807	4·102	17	1,248	6·338
6	1,156	5·872	18	1,276	6·482
7	1,242	6·310	19	1,034	5·251
8	1,158	5·881	20	836	4·248
9	[illegible]	3·972	21	910	4·621
10	903	4·589	22	972	4·936
11	1,159	5·887	23	1,009	[illegible]
12	1,313	6·669	24	959	4·872

Mean velocity, per second ... ... 5·336 metres.
" " per minute ... ... 1,050 feet.
Mean area of the place of air measurement ... ... 3·4459 square metres.
" " " " ... ... 37·1 square feet.
Volume of air, per second ... ... 18·388 cubic metres.
" " per minute ... ... 38,964 cubic feet.
Maximum velocity, per second ... ... 6·690 metres.
" " per minute ... ... 1,317 feet.
Ratio of maximum to mean velocity ... ... 1·254

EXPERIMENT No. 6, FIG. 12, PLATE VI.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No.	Feet per Minute.	Metres per Second.
1	301	1·527	13	449	2·282
2	374	1·900	14	371	1·887
3	356	1·810	15	328	1·667
4	321	1·629	16	448	2·278
5	294	1·496	17	460	2·336
6	[illegible]	2·205	18	457	[illegible]
7	[illegible]	2·335	19	363	1·848
8	431	2·189	20	[illegible]	1·630
9	[illegible]	1·723	21	374	1·906
10	[illegible]	1·720	22	372	1·891
11	424	2·154	23	376	1·910
12	492	[illegible]	24	334	1·696

Mean velocity, per second ... ... 1·986 metres.
" " per minute ... ... 391 feet.
Mean area of the place of air measurement ... ... 3·5078 square metres.
" " " " ... ... 37·8 square feet.
Volume of air, per second ... ... 6·967 cubic metres.
" " per minute ... ... 14,763 cubic feet.
Maximum velocity, per second ... ... 2·500 metres.
" " per minute ... ... 492 feet.
Ratio of maximum to mean velocity ... ... 1·259

EXPERIMENT No. 7, FIG. 14, PLATE VI.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No.	Feet per Minute.	Metres per Second.
1	677	3·440	13	786	3·994
2	757	3·846	14	657	3·340
3	675	3·428	15	827	4·203
4	589	2·994	16	812	4·124
5	866	4·401	17	803	4·080
6	922	4·685	18	703	3·570
7	905	4·595	19	655	3·325
8	667	3·387	20	614	3·117
9	671	3·408	21	624	3·171
10	865	4·393	22	596	3·026
11	826	4·194	23	518	2·629
12	851	4·321			

Mean velocity, per second ... ... 3·793 metres.
„ „ per minute ... ... 747 feet.
Mean area of the place of air measurement ... ... 3·0737 square metres.
„ „ „ „ ... ... 33·1 square feet.
Volume of air, per second ... ... 11·658 cubic metres.
„ „ per minute ... ... 24,703 cubic feet.
Maximum velocity, per second ... ... 4·700 metres.
„ „ per minute ... ... 925 feet.
Ratio of maximum to mean velocity ... ... 1·239

EXPERIMENT No. 8, FIG. 16, PLATE VI.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No.	Feet per Minute.	Metres per Second.
1	521	2·645	13	493	2·505
2	649	3·299	14	459	2·331
3	612	3·108	15	588	2·985
4	506	2·569	16	646	3·281
5	633	3·216	17	581	2·950
6	672	3·415	18	551	2·797
7	561	2·848	19	559	2·838
8	532	2·704	20	535	2·720
9	545	2·771	21	614	3·118
10	627	3·186	22	609	3·096
11	650	3·300	23	558	2·833
12	503	2·555	24	513	2·608

Mean velocity, per second ... ... 2·878 metres.
„ „ per minute ... ... 567 feet.
Mean area of the place of air measurement ... ... 2·7693 square metres.
„ „ „ „ ... ... 29·8 square feet.
Volume of air, per second ... ... 7·970 cubic metres.
„ „ per minute ... ... 16,888 cubic feet.
Maximum velocity, per second ... ... 3·420 metres.
„ „ per minute ... ... 673 feet.
Ratio of maximum to mean velocity ... ... 1·188

EXPERIMENT NO. 9, FIG. 17, PLATE VI.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No.	Feet per Minute.	Metres per Second.
1	906	4·604	11	974	4·947
2	1,144	5·812	12	842	4·275
3	999	5·075	13	879	4·465
4	749	3·807	14	1,055	5·357
5	1,109	5·633	15	1,069	5·431
6	1,091	5·542	16	957	4·860
7	995	5·053	17	758	3·852
8	827	4·201	18	960	4·875
9	1,019	5·176	19	979	4·971
10	1,057	5·368	20	719	3·655

Mean velocity, per second ... ... 4·875 metres.
„ „ per minute ... ... 960 feet.
Mean area of the place of air measurement ... ... 2·0086 square metres.
„ „ „ „ ... ... 21·6 square feet.
Volume of air, per second ... ... 9·792 cubic metres.
„ „ per minute ... ... 20,749 cubic feet.
Maximum velocity, per second... ... ... 5·860 metres.
„ „ per minute ... ... 1,153 feet.
Ratio of maximum to mean velocity ... ... 1·202

EXPERIMENT NO. 10, FIG. 18, PLATE VI.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No.	Feet per Minute.	Metres per Second.
1	457	2·321	13	743	3·772
2	676	3·433	14	508	2·581
3	765	3·887	15	683	3·214
4	534	2·714	16	918	4·665
5	513	2·606	17	969	4·923
6	1,043	5·297	18	849	4·314
7	1,055	5·358	19	631	3·204
8	911	4·629	20	881	1·937
9	724	3·676	21	801	4·070
10	553	2·809	22	922	4·684
11	988	5·021	23	794	4·033
12	977	4·964	24	477	2·425

Mean velocity, per second ... ... 3·781 metres.
„ „ per minute ... ... 744 feet.
Mean area of the place of air measurement ... ... 3·4894 square metres.
„ „ „ „ ... ... 37·6 square feet.
Volume of air, per second ... ... 13·194 cubic metres.
„ „ per minute ... ... 27,958 cubic feet.
Maximum velocity, per second... ... ... 5·470 metres.
„ „ per minute ... ... 1,077 feet.
Ratio of maximum to mean velocity ... ... 1·447

EXPERIMENT No. 11, FIG. 19, PLATE VI.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No.	Feet per Minute.	Metres per Second.
1	174	0·885	13	552	2·802
2	336	1·707	14	361	1·832
3	420	2·136	15	293	1·490
4	338	1·715	16	433	2·200
5	243	1·232	17	543	2·757
6	455	2·312	18	571	2·903
7	547	2·779	19	435	2·211
8	534	2·712	20	282	1·430
9	382	1·943	21	396	2·011
10	174	0·883	22	450	2·285
11	396	2·012	23	416	2·114
12	532	2·702	24	339	1·722

Mean velocity, per second ... ... 2·147 metres.
„ „ per minute ... ... 423 feet.
Mean area of the place of air measurement ... ... 3·2480 square metres.
„ „ „ „ ... ... 34·9 square feet.
Volume of air, per second ... ... 6·973 cubic metres.
„ „ per minute ... ... 14,775 cubic feet.
Maximum velocity, per second... ... ... 2·950 metres.
„ „ per minute ... ... 581 feet.
Ratio of maximum to mean velocity ... ... 1·374

EXPERIMENT No. 12, FIG. 20, PLATE VII.—OBSERVED VELOCITIES.

No.	Feet per Minute.	Metres per Second.	No.	Feet per Minute.	Metres per Second.
1	424	2·154	11	464	2·357
2	574	2·914	12	251	1·275
3	554	2·814	13	540	2·741
4	380	1·932	14	582	2·958
5	462	2·347	15	441	2·240
6	572	2·905	16	337	1·710
7	529	2·685	17	432	2·192
8	363	1·843	18	541	2·746
9	456	2·314	19	480	2·438
10	567	2·882	20	353	1·795

Mean velocity, per second ... ... 2·383 metres.
„ „ per minute ... ... 469 feet.
Mean area of the place of air measurement... ... 2·0039 square metres.
„ „ „ „ ... ... 21·5 square feet.
Volume of air, per second ... ... 4·775 cubic metres.
„ „ per minute ... ... 10,118 cubic feet.
Maximum velocity, per second... ... ... 3·020 metres.
„ „ per minute ... ... 594 feet.
Ratio of maximum to mean velocity... ... ... 1·267

(To be continued.)

The PRESIDENT said that Mr. Murgue's paper was a very valuable contribution to the literature on the ventilation of mines, and his experiments were very interesting. Of course it would be very expensive if all of the airways of a mine were lined with masonry. Still, he thought the paper had a practical bearing, at all events, in bringing to their minds the great variation in the frictional resistances under the different conditions found in mines. Of course the great point was, that the views put forth were largely theoretical, and to deal theoretically with the different experiments was one thing, while it was quite another to adduce what was the practical value of Mr. Murgue's paper. Still, a mining engineer ought to be able to form a perfectly clear idea as to what might be the future ventilation of his mine; and, so far as he could follow the paper, Mr. Murgue seemed to have made some considerable additions to the experiments of Messrs. Péclet, Atkinson, Greenwell, and others, who had endeavoured to arrive at the value of the coefficient of friction in mines.

Mr. T. A. SOUTHERN (Derby) said Mr. Murgue's paper was a valuable one, and that the experiments had been conducted very successfully. It, however, occurred to him that Mr. Murgue was a little premature in advancing his conclusions, or, at all events, his figures. He thought that the number of experiments was too limited to enable him to give definite values for the coefficient of friction. These experiments clearly showed that the ordinarily accepted values were entirely wrong. He had made some observations himself, and the results showed that the water-gauge which would have been required to overcome the friction would have been an impracticable water-gauge—something like 20 inches. He thought it was very interesting and instructive for the Institution to have experiments put before them to show with some force the advantage of smooth surfaces in airways, and of direct airways as compared with rough surfaces and crooked roads. He hardly thought that any number of experiments would ever show how an airway should be lined. He thought it would vary with the nature of the roof and sides, and that it would be cheaper to spend money in increasing the ventilation by enlarging the roads. The author spoke of being able to read the water-gauge to ·0004 inch. The surface of water in a small tube assumed a curved form, and he wanted to know whether it always retained exactly the same form, because if it did not, he thought the reading of the difference of pressure would be affected by the change.

Mr. J. C. B. HENDY (Etherley) wrote that Mr. Murgue's paper would have been even more valuable if the experiments had been made on underground roads of greater length. The longest length experimented

on was only 1,085 feet, whereas it was a common thing to have airways from 4,000 to 5,000 feet in length and even much more, in a mine.

Mr. M. Deacon (Alfreton) wrote that he had for some time been making experiments for the purpose of endeavouring to establish reliable values of the coefficient of friction of air in mines, and he had intended to communicate the results when completed to the Federated Institution of Mining Engineers. The excellent paper by Mr. Murgue, in which he dealt with the subject in such a very able and complete manner would enable him to give the results of his tests in discussion instead of communicating a paper on the same subject. So far as Mr. Murgue's tests went, namely:—as applied to practically straight airways, they were doubtless as correct as possible, but in his (Mr. Deacon's) opinion the values were generally too low for the practical purposes of the mining engineer. The value obtained in experiment No. 12, k = 0·00241, approximated very closely to the result obtained in one of his (Mr. Deacon's) tests upon the whole of one district in a mine (the other districts being boarded off during the test) in which the airways were 1,279 yards long with ragged sides, 50 square feet in area, very little timber being used, and 578 yards of face with timber at intervals of 4 feet, and 24 square feet in area. At a velocity of 475 feet per minute, k = 0·0023. At higher velocities, the value fell to k = 0·0019 and k = 0·0017. In another experiment (made with the pit top-doors open) the air being drawn through the fan-drift, the average area of which together with the short length of upcast shaft through which the air travelled before reaching the drift was 140 square feet, all in masonry, the value of k increased to 0·007. Further tests are being made to verify the previous results which will be communicated at the adjourned discussion. In the meantime it would be interesting and instructive if Mr. Murgue would make further experiments on the effect of sharp bends, and of very high velocities, upon the value of the coefficient of friction.

The President then moved a cordial vote of thanks to Mr. Murgue for his valuable paper, which was unanimously agreed to.

Mr. D. Murgue (St. Etienne) wrote that he was much honoured by the cordial vote of thanks which had been moved by the President. In reply to Mr. T. A. Southern, who expressed a doubt that the curved form of the surface of the water in the small tube did not always retain the same form, he (Mr. Murgue) answered that he avoided that cause of error by using a tube nearly 2 inches in diameter, a dimension which appeared to him to be sufficient to reduce the perturbating effects of capillarity to a minimum. One of the speakers regretted that the

to Air-currents in Mines."

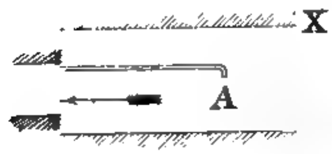


FIG. 6.

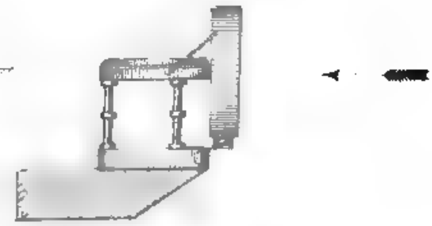


FIG. 5.

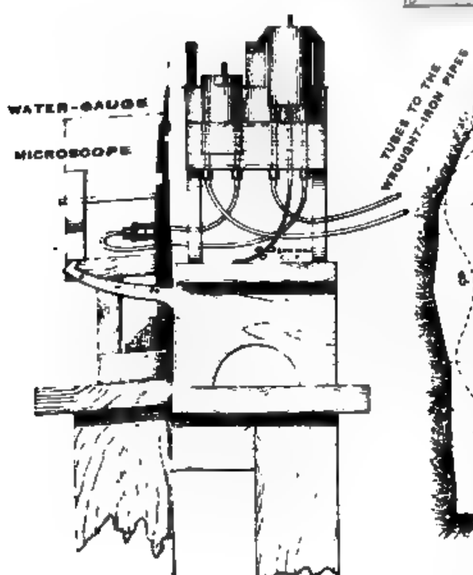
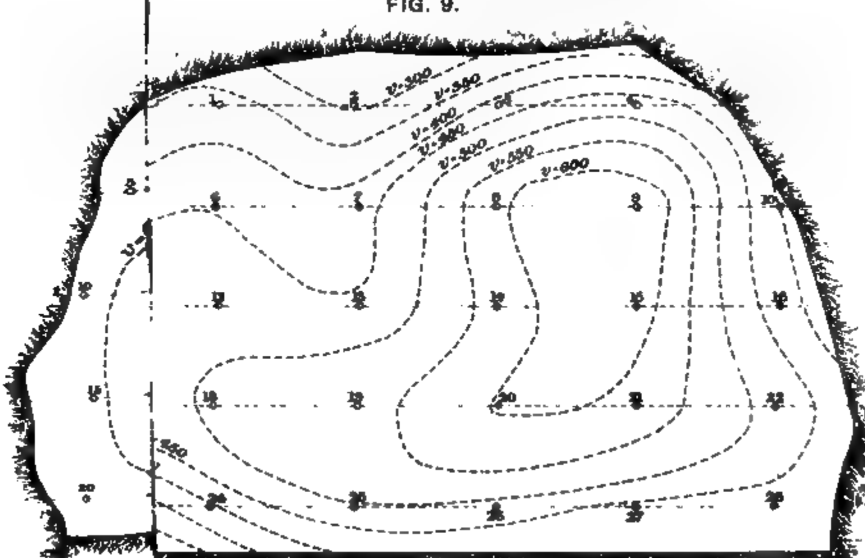


FIG. 10.

EXPERIMENT No. 4

Scale 2½ Feet to 1 Inch

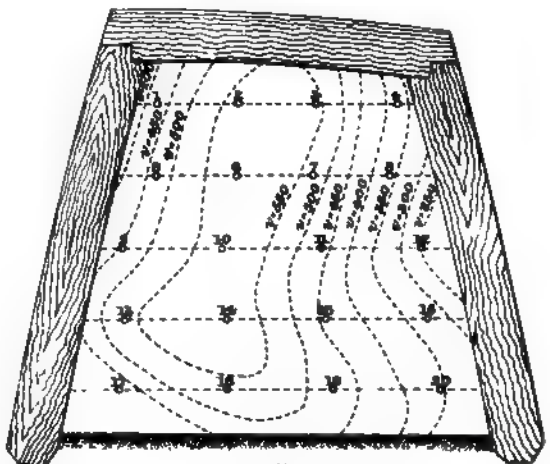
FIG. 9.



EXPERIMENT No. 3

To illustrate Mr. D. Murgue's Paper on "The Friction of or Resistance to Air-currents in Mines."

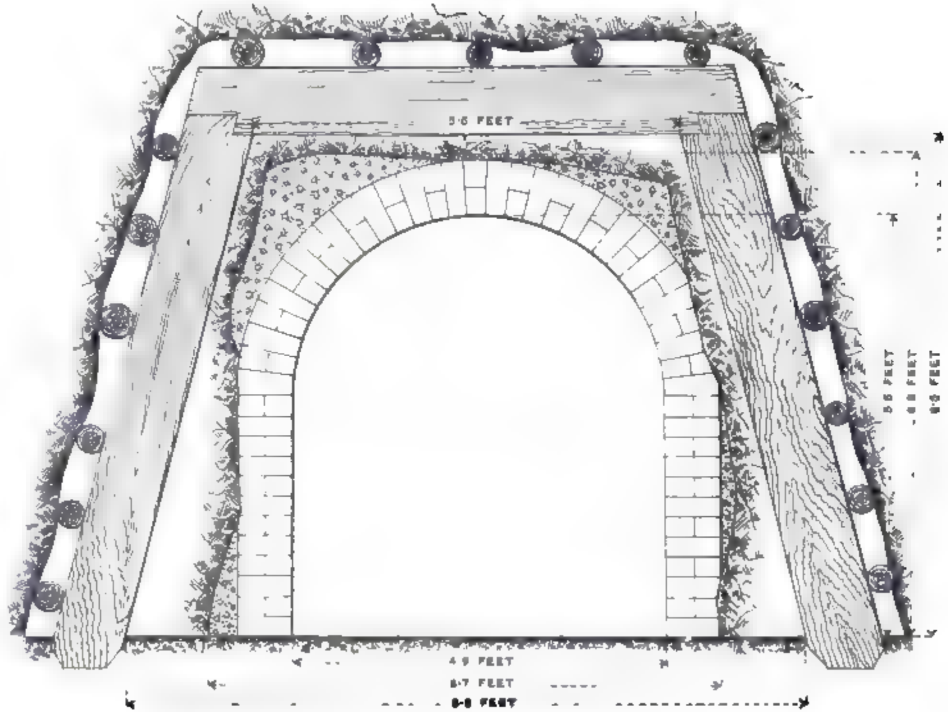
FIG. 20.



EXPERIMENT No. 12.

Scale 2½ Feet to 1 Inch

FIG. 21.



Scale 2½ Feet to 1 Inch

Andw Reid Sons & Co. Lithos. Newcastle

DISCUSSION ON MR. R. T. MOORE'S PAPER ON "THE MINERAL OIL INDUSTRY OF SCOTLAND."*

Mr. H. M. CADELL (Bo'ness) said he had read Mr. Moore's paper with great interest. Little had been written on the subject, and it was only recently that a geological map of the shale districts had been published. Mr. Moore spoke of some shales that were new to him, one was the Jubilee shale, another was the Maybrick, were these two shales of any great value?

Mr. RALPH MOORE (Glasgow) said the two shales referred to were worked at the Holmes oilworks, a few miles from Bathgate. One, he thought, was 5 or 6 feet thick, and the other 12 or 13 feet. They were not first-rate shales, but they yielded, he thought, about 18 or 20 gallons of oil per ton.

Mr. H. M. CADELL said he understood what Mr. Moore meant now, these names were given to different parts of the Pumpherston shales.

Mr. HENRY AITKEN (Falkirk) said that Mr. Moore's paper had almost exhausted the subject. The main difficulty the shale-worker had to contend with was not the want of shale but the want of money for the products. It was a very young industry. Practically only one generation had worked at it, and there were many directions in which economy might be effected. It was a question for younger men with the experience of others to pull it through, but it would be a hard pull, and unless there was an immediate change some, at all events, would have to go down in the struggle for existence. There were other shales farther down in the section than those mentioned by Mr. Moore in his paper, but as far as he had investigated them, they were, as a rule, of poor quality, at least so far as their oil yielding properties went. There was, however, plenty of shale, but as he had said before, the difficulty was to cook it and obtain the products with profit.

The discussion then closed.

DISCUSSION ON PROF. F. CLOWES' PAPER ON "A PORTABLE SAFETY-LAMP WITH ORDINARY OIL ILLUMINATING FLAME, AND STANDARD HYDROGEN-FLAME, FOR ACCURATE AND DELICATE GAS-TESTING."†

Prof. F. CLOWES wrote that the hydrogen-flame is the most delicate and accurate indicator and measurer of gas known. Whilst burning in the lamp, this flame maintained itself even in an air-current far more

* *Trans. Fed. Inst.*, vol. iv., page 36. † *Trans. Fed. Inst.*, vol. iv., page 441.

rapid than that used for ventilating the pit: a current in which the flame of oil or alcohol was immediately extinguished. On the other hand, the hydrogen-flame was immediately extinguished when exposed to an explosive current. The tube which fed the hydrogen into the lamp was proved, even when it was freely open, to be absolutely incapable of passing flame, a rapid and explosive current. Since the percentage of gas present in the air is ascertained by observing the height of the cap, careful measurements of the cap-heights for known percentages were made and recorded in the paper; and it was then stated that these heights could be judged with reasonable accuracy by a mere inspection of the cap. The difficulty of using a measuring-scale within the lamp was found to be great, owing to the very feeble lighting power of the flame and more especially of the cap. This difficulty has now, however, been surmounted by placing a ladder-like open metal scale close to the flame, and between the flame and the eye. The steps of the ladder, seen against the cap as a background, serve to measure the height of the cap, and to give the percentage of gas present in the air with great accuracy. Fig. 1 is a sectional diagram of the lamp with the hydrogen attachment, and the measuring-scale shown in position. The lowest step of the scale is used to set the hydrogen-flame to the standard height of 0·4 inch (10 millimetres). When the tip of the flame just touches this step, the flame is of standard dimensions. The other steps indicate respectively the following percentages of gas: 0·25 and 0·5, 1·0, 2·0, 3·0. But since the top of the cap is too pale to show up the step, it has been found necessary to place the step in each case 0·2 inch below the tip of the cap; the step thus becomes plainly visible as a black bar against the cap. Fig. 2 is the chart which is printed on stout card, and is furnished for use belowground in translating the readings of the caps against the measuring scale into percentages. It will be seen that the scale serves to measure from 0·25 to 3 per cent. of gas when the standard hydrogen-flame is used in the lamp; and that the same scale measures 4 and 5 per cent. when the oil-flame is in use, while 6 per cent. of gas gives a cap which just reaches the top of the lamp-glass, and is thus easily identified. The use of the chart would naturally become unnecessary as soon as the observer became familiar with the indications of the lamp. It will be

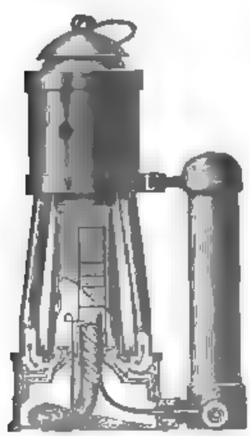


Fig. 1

noted that the caps corresponding to 0·25 and 0·5 per cent. of gas do not differ in height. These caps, however, are readily distinguished from one another by a very marked difference in their appearance. The cap due to 0·25 per cent., although perfectly visible, is unusually pale and hazy in its outline, while the 0·5 per cent. cap is much more definite in its margin as well as more substantial; even a novice in gas-testing sees the cap due to 0·25 per cent. of gas and easily distinguishes it from that due to 0·5 per cent. It will be understood that in preparing the measuring-scale, the hydrogen-flame has in every case been set to its standard height in the air containing gas. In other words the hydrogen-flame used in every test was precisely 0·4 inch in height, whilst the cap was

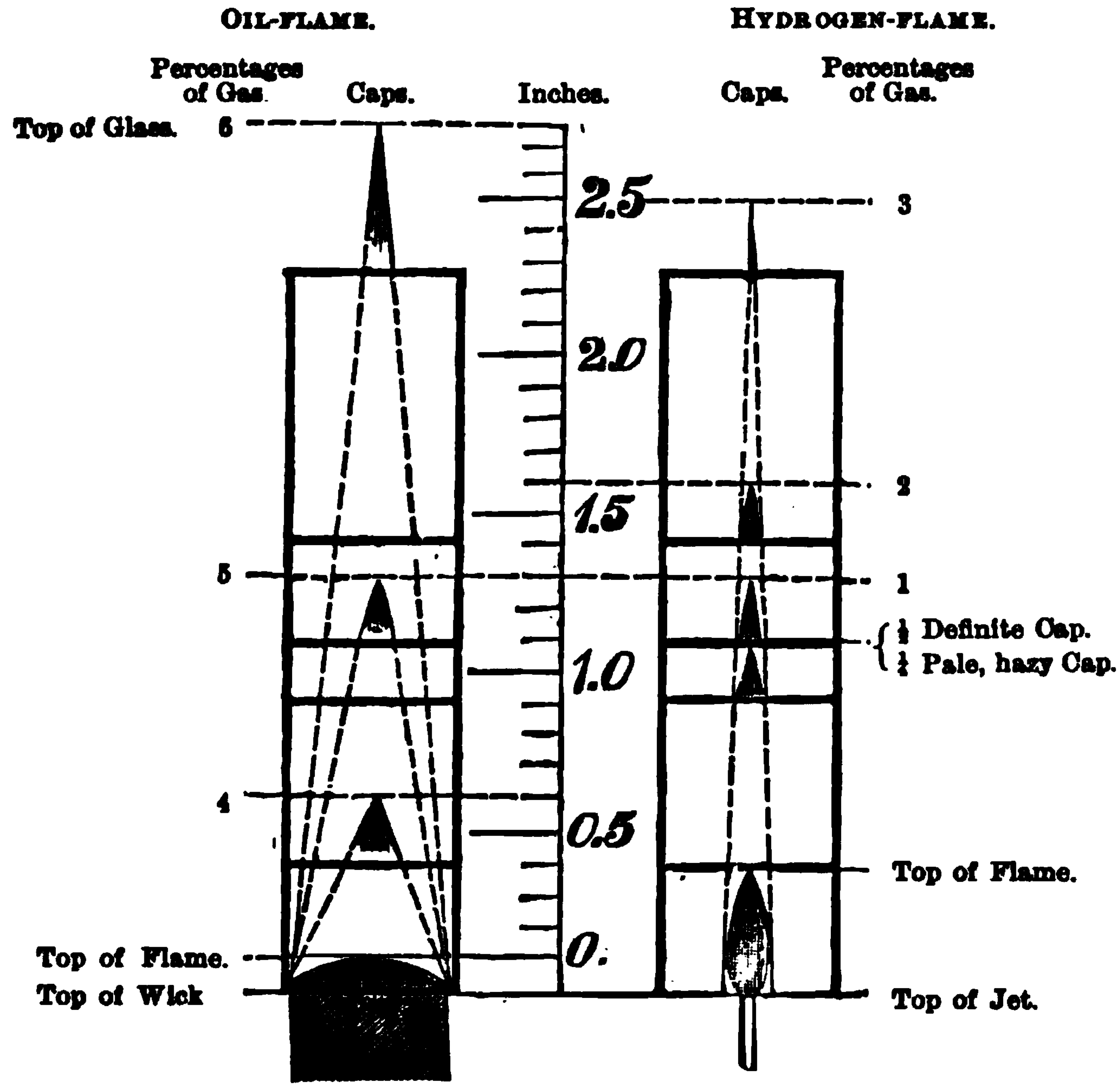


Fig. 1.

being read. Thus the difficulty of removing the lamp to gas-free air for its adjustment, or the error introduced into other lamps by the neglect of the above precaution, is entirely avoided. A correct measurement of the percentage of gas present can be made on the spot and in 30 seconds, reckoning the time from the lamp with its oil-flame fully burning, to the return to the same condition. The long series of tests to which this lamp was at first subjected were made in experimental apparatus above-ground, partly in the laboratory, and partly in the neighbourhood of the pit. Its safety, delicacy, accuracy, and handiness were thus carefully examined and proved. The interpretation of its indications were also

reduced to scale. The lamp has now been further subjected to extended use underground, in the hands of scientific men, of engineers, and of managers of mines. There is a general agreement as to its suitability and convenience, while the results it has furnished agree with thôse which might be reasonably expected, and with the indications yielded by the Liveing apparatus. The cooling of the lamp-glass by the ventilating current causes water from the hydrogen-flame to condense in small drops on the inside of the glass, when the hydrogen-flame is burnt continuously for several minutes. These drops interfere with the perception of the cap; they are, however, quickly dissipated by turning up the oil-flame. But the formation of drops on the glass is prevented either by partly covering the glass, or by using the hydrogen-flame only for a few seconds at a time; and this is amply sufficient for making a test, while it is wise to economize the gas by not burning it unnecessarily. Misapprehension has arisen as to the purpose for which the lamp has been designed. It is not intended to be used by the working miner, although when the hydrogen attachment is removed it serves perfectly well for illuminating purposes. It is simply an ordinary lamp adapted to receive the special hydrogen fittings, and it can be used either with or without these special attachments. The lamp is, however, intended to be placed in the hands of more responsible officials, and to be applied to delicate and careful examination for gas in the return airways, so as to assist in the regulation and proper subdivision of the ventilating current. The special hydrogen fittings can be adapted to any lamp, provided the glass is of sufficient length; but the form of lamp described is in every respect the most suitable. It should be remembered that the presence of gauze around the flame and cap is a great hindrance to the perception of the caps given by small percentages of gas. The cylinders containing the compressed hydrogen cannot be a source of danger. They are never exposed to an internal pressure exceeding 1,500 lbs. per square inch, and they are tested in all cases by the makers to a pressure of 3,000 lbs. per inch, or double their actual working pressure, before being sent away. Similar cylinders of much larger size have been in use for the storage of compressed gases for many years, and without accident from bursting. The regulation of the hydrogen-flame within the lamp has been effected at once by mine officials without the slightest difficulty.

Mr. George Lewis (Derby) said there was no doubt that Prof. Clowes' lamp was a great advance in the methods of detecting small quantities of gas.

The discussion was then closed.

DISCUSSION ON MR. ARNOLD LUPTON'S AND MR. JOEL SETTLE'S PAPERS ON "SPONTANEOUS COMBUSTION IN COAL-MINES."*

Mr. H. AITKEN (Falkirk) said that they were greatly in want of knowledge as to the cause of spontaneous combustion of coals. Many engineers considered that it was caused entirely by pyrites. His opinion was that the pyrites was not the sole cause, and he was not at all sure that pyrites played any part in it. His idea was that spontaneous combustion of coal was caused by the oxidation of the hydrocarbons. He knew one coal-seam in which the sulphur amounted to only 0·3 per cent., but when put in a bing only 5 feet high it took fire in a few days. In opening out this seam he found that the temperature of the stoops rose from about 50 degs. to 90 degs. Fahr., and in a few days the temperature fell to its normal condition. He would suggest that coal known to be liable to spontaneous combustion should be loaded into an old ship in the usual way, closed up and kept in dock, and the gases given off tested daily. In this way it might be possible to ascertain what was the cause of the spontaneous heating and its cure.

Mr. D. A. LOUIS (London) said that it seemed pretty certain that spontaneous combustion did arise from the oxidation of hydrocarbons. Spontaneous combustion could never take place in absolutely solid coal, as had been asserted by some to be the case. The heating always occurred in fissures in standing coal or in broken coal, or in fact only at any surface where the oxygen of the air could come into intimate contact with the hydrocarbons of the coal, and therefore the more extensive the surface of coal presented to the air (that is the finer the subdivision of the coal) the more readily would spontaneous combustion ensue, and the more vigorous would the conflagration be with the same coal. The chemical and physical characters of the carbonaceous matter of coal are apparently the ruling factors influencing liability to spontaneous combustion. The heat produced by the oxidation of the iron pyrites in the coal would not of itself be sufficient to ignite the coal.

Mr. GEORGE LEWIS (Derby) did not know if the mines of Scotland were subject to spontaneous combustion, but if they were he thought the Scotch members might give some information upon the subject. With regard to the statement that there was no instance of spontaneous combustion occurring in solid coal, he did not agree with it. He did not see how it was possible for solid coal to fire externally. It might be so, but he would require strong evidence before he could believe it would fire.

* *Trans. Fed. Inst.*, vol. iv., page 481; and vol. v., page 10.

As regarded the cause, he was in accord with the last speaker, but he thought that, as mining engineers, they required a little more information on the subject. They wanted to know not only how the fire had originated, but the best way of preventing it. He was under the belief that prevention was better than cure; and, if by any way they could prevent these fires, he thought it was very desirable. As mining engineers they ought to bring their information to bear on the subject.

Mr. RALPH MOORE (Glasgow) said there was a fire in Dalmeny shale workings, but whether it arose from spontaneous combustion or not he did not know. He then added that the Dysart coal and a coal seam at Lochgelly in Fifeshire were liable to spontaneous combustion.

Mr. LANDALE (Lochgelly) said that in the splint and parrot seam in Fifeshire when the roof-coal comes down in the waste, it, and the small coal left underground, are subject to spontaneous combustion. This generally occurred in places where there is little or no ventilation. Where small coal is left underground, it, along with something in the material which formed the roof, seemed to originate the fire. Keeping the waste cool by better ventilation, and clearing out all small coal, were the only preventives yet found. The material from the roof had been analysed, but nothing had yet been discovered to account for the spontaneous combustion.

Mr. CADELL (Bo'ness) said Mr. Louis had said that he did not think spontaneous combustion could be produced by the heat arising from the decomposition of pyrites. The members who visited Bardykes colliery on the previous day had an example to the contrary, in the large bing of blaes from the washing machines by the Lührig process. The bing was slowly burning, and if the Lührig process was working properly there should have been no coal included in the blaes or fireclay refuse. This rubbish was highly impregnated with pyrites, and it seemed to him that there was conclusive proof that the pyrites had set fire to the whole bing. In the face of that fact, he thought it was possible for pyrites to develop enough of heat to produce spontaneous combustion.

Mr. D. A. LOUIS said that heat was produced in considerable quantities by the decomposition of pyrites, but it was not very strong locally, and at Bardykes colliery, in the heaps referred to by Mr. Cadell, was not sufficient to ignite sulphur, a substance which ignited at a lower temperature than coal. The results of ventilation on spontaneous combustion would, in his opinion, be somewhat to the following effect:—Supposing they had a strong current of air passing through the district, and that the temperature had not yet got to the point where the coal was ignited,

then the current would have the effect of cooling the coal down and probably prevent its ignition; but supposing ignition had already set in, the effect would be to make it burn more vigorously.

Mr. Ralph Moore (Glasgow) said, in regard to sulphur, those members who had seen black-band ironstone bings burning must have seen sulphur on the surface on the top of the bing.

Mr. T. A. Southern (Derby) said it was acknowledged that large masses of pyrites might become heated, yet in the maudlin seam in the county of Durham, a thick band of pyrites was abstracted from the coal and left underground. Nevertheless gob-fires were unknown.

Mr. J. B. Atkinson (Glasgow) said there was a coal-seam worked at Brora, in Sutherlandshire, which was peculiarly liable to spontaneous combustion, and the coal contained a high percentage of sulphur. The Dysart coal in Fife and the ell coal of Lanarkshire did not contain much sulphur, yet they were subject to spontaneous combustion. The Dysart coal was peculiarly subject to fires, and great pains had been taken to devise a safe system of working. The general idea was to get the old workings well stowed, and to leave no openings. Recently he had seen some 500 or 600 tons of screened small coal from the Dysart seam which had taken fire after lying for a few days near the pit-head, and it was expected that the fire would go through the whole mass.

Mr. H. M. Cadell (Bo'ness) said, with regard to the blaes-bing at Bardykes, Mr. Louis had said there was not heat sufficient to ignite the sulphur. The inside of the bing was, where exposed, found to be completely charred and reddened, the ironstone particles being calcined in a way which showed that the mass must have been heated to redness at least, presumably by the decomposition of the pyrites.

Mr. D. A. Louis pointed out that an ordinary way of oxidizing pyritic ore in many localities was to heap it up in the air on billets of wood, but then the heat required was started by applying ignited wood or charcoal to the heaps, and was sustained partly by the oxidation of the sulphur, and partly by the combustion of the carbonaceous matter present in the ore, or previously mixed with it for that purpose. Ordinarily the decomposition of pyrites, when mixed with other earthy substances as in the Bardykes heaps referred to, proceeded through various stages of oxidation without necessarily being raised to a red-heat.

Mr. Scott said that in the South Staffordshire district they had arrived at the conclusion that oxidation alone was the cause of spontaneous combustion. The thick coal-seam had been used for centuries for blast-furnace work because it was free from sulphur; yet in this seam spontaneous

combustion was common, and it occurred in all sorts of forms. They went along the main road of a pit and saw the fine coal-dust by the side of the road on fire, and they found fire in the fissures of the coal. He quite agreed that solid coal could not fire, but if they found a fissure in it, this would be found charged with fine coal which was red-hot. There were other classes of gob-fire; and, as he had said, they had arrived at the conclusion that oxidation alone was the cause of spontaneous combustion in the South Staffordshire district.

Mr. W. F. CLARK (Birmingham) said that the stinking or sulphur coal of South Staffordshire (lying underneath the ten-yard coal) was full of pyrites, and that seam was practically free from gob-fires.

Mr. E. B. WAIN (Stoke-upon-Trent) instanced a case where coal was stacked on the surface during the recent hot weather, and showed no signs of heating until rain came, when it began to heat. In less than three days from the time it was first observed, the temperature, taken 12 feet below the top of the stack, was found to be 580 degs. Fahr. The coal was almost, if not entirely, free from sulphur, and was from a seam in which gob-fires were unknown. It only gave trouble when stacked on the surface in bulk, coal and slack together, as drawn from the pit. As the coal was loaded away, the heated portions cooled down rapidly.

Mr. GARFORTH (Normanton) mentioned the case of a gas coal, through which no less than four or five ships, with cargoes varying from 1,500 to 2,500 tons had been entirely destroyed. He had, at different times, stocked 7,000 to 10,000 tons of it, always taking the precaution to pass the coal over ½ inch screens, when it did not take fire. When it was stocked unscreened it invariably took fire. At an enquiry held by the Board of Trade as to the cause of such fires on ship-board, he gave evidence and said the pyrites picked out in the process of screening and passing the coal over the ½ inch screens would principally account for the fires. He should like to have the subject discussed further, as he thought they might be able to supplement the report which was published some fifteen years ago, in which the Commissioners, after going to different parts, laid great stress on the breakage of coal in the process of shipping.

The PRESIDENT said they always had interesting discussions on spontaneous combustion. Referring to what he considered as a rather curious instance of spontaneous combustion in a very thick seam in a pit of which he had the management, and which was wrought on the pillar-and-stall system, he said it did not take fire immediately at the wall-sides in the

passages, but they felt it getting very warm in certain places. On breaking into a pillar, say, 2 feet, they found the coal very hot, and if left too long a considerable amount of burning matter was found. There was a considerable amount of air passing along the passages, but where pillars were worked it was less, and frequent fires took place.

The discussion was then closed.

DISCUSSION ON SIR ARCHIBALD GEIKIE'S PAPER ON "THE WORK OF THE GEOLOGICAL SURVEY."*

Mr. Henry M. Cadell (Bo'ness) said he had read Sir Archibald Geikie's account of the work of the Geological Survey with very great interest. A paper such as that was, he thought, of great value and importance to practical geologists, as it set forth in the author's wonted lucid and graphic style, the nature of the work, progress, and organization of one of the most important practical, as well as scientific departments of the Civil Service. The Geological Survey and its admirable work deserved to be better known and appreciated, and this paper supplied, he thought, much useful information which the public ought to possess on the subject. Sir Archibald Geikie had alluded to the sale and prices of the maps, and he (Mr. Cadell) thought that a few words of friendly criticism might not be amiss In most mercantile businesses it was the custom to advertize the articles sold, and increase the agencies for their sale in different parts of the country. The opposite principle seemed to actuate the Education Department, of which the Geological Survey was a branch; advertizing a new map or taking any means to push the sale of a Geological Survey publication was apparently a departure too sensible to be dreamt of. In Scotland, so far as as he knew, there was but one agency for the sale of the Geological Survey's publications—Messrs. W. & A. K. Johnston in Edinburgh—and in England there were scarcely, if any, more. No wonder that the general public knew scarcely anything about the Geological Survey and its work. In other countries the Geological Survey maps were sold in an ordinary business-like way. In Saxony, for example, to facilitate the sale of the geological maps agencies had been established in all the important towns, and up till January, 1893, nearly 17,000 copies of maps, etc., had been sold, a proof that the scientific and practical utility of the Geological Survey was appreciated by the public as soon as the matter was put before them in a sensible way. The British Geological Survey maps were again all engraved in outline on copper and

* *Trans. Fed. Inst.*, vol. v., page 142.

hand-coloured—a system of colouring which so far as he knew was almost peculiar to our islands. The reasons for this were given by the Director-General as being:—(1) the printing of the maps in colours was impracticable from the system of engraving adopted; and (2) the advantage in making alterations without re-engraving a whole edition of a map which the present system possessed. Now it appeared to him (Mr. Cadell), that these objections to printing in colours were less weighty than the objections to engraving on copper and colouring by hand. Were the maps adequately advertized and sold by numerous agents all over the country there would be an absolute certainty of a much larger sale, and after a certain number of copies were sold the initial outlay would be repaid, and there would be a substantial profit on all the remaining copies of the edition. At present the maps were coloured by women in London, and he was sure that in many cases the maps were sold at a great loss. In any case there was no more profit in selling 1,000 than in selling 100, so that from this point of view there was no inducement to the department to push their trade. The advantages claimed for hand-colouring in the way of giving facilities for alterations from time to time were, he thought, exaggerated; for the general public (who were the largest purchasers) were not so particular about minor mistakes in the maps as was supposed. And it was well known that although many of the present sheets had for years been antiquated they were still sold without corrections, as being infinitely better than no maps at all. Regarding the technical difficulties referred to by the Director-General, it seemed to him that the British Government could surely now find a way to print maps in colours as accurately as any other government, seeing that great advances in the art of lithography had been made within the last decade or two. Hand-coloured maps again were liable to fade, and were injured by the least damp, in addition to which the colouring was often less uniform in tone than could be desired. Sir Archibald Geikie stated that no less than 180 different tints and combinations of colours were employed. Now here again was an argument against hand-colouring. Where so many tints were employed, it was often impossible to prevent confusion, as the primary colours were only three in number and of necessity many of their combinations must very closely resemble one another. By adopting the method of printing, a large number of these complications might be avoided, as sundry systems of stippling could be judiciously introduced without unduly interfering with the general harmony of colour or the topography of the maps, and would greatly add to their geological perspicuity, and subtract from the expense of multifarious costly printings which would be

otherwise involved. The work of the Geological Survey in the mineral districts was again, he thought, in Scotland at least, deserving of more attention, and many of the maps were sadly out of date. These sheets were of course those that might be expected to sell best, and should consequently be regularly kept up to date. Instead of pushing on so rapidly to complete the mapping of the remote Highlands, he (Mr. Cadell) thought that a greater part of the energy of the staff might well be diverted, during the winter months at least, towards the collection of mining information, and the publication of new editions of the mineral maps with sections and accompanying memoirs, which would be of greater public utility than the almost purely scientific branch of the work. The Director-General was fully alive to this question, but the Treasury had hitherto been very unwilling to allow any district to be resurveyed while there were still any unsurveyed parts of the country. This appeared to him (Mr. Cadell) to be false economy, and he thought such a body as he was addressing were well qualified to express their views to the Government, and should bring the weight of their valuable opinion to bear on the Treasury and induce them to sanction the resurvey of the mineral fields, altogether irrespective of the progress of the survey in the more outlying districts. The Geological Survey was a most valuable public institution, and was fortunate in having so able and distinguished a chief as the present Director-General, and such a brilliant though numerically small staff of workers under him. The work of the Geological and Ordnance Surveys was the admiration of geologists and topographers in all countries, and in making these remarks he (Mr. Cadell) had no wish to speak in a hostile or carping spirit. He had at one time been a member of the staff himself, and would always cherish the kindest feelings towards the Survey and all its interests, but being now most interested in the practical department of the stony science he might be excused for regarding the matter from a practical and business point of view; and he hoped these observations might lead to the consideration in the proper quarter of the points he had thus imperfectly endeavoured to bring forward. The few thousands spent yearly by Government on geological examinations of the country was money well expended, and the Survey had much more to show for it than many other more popular departments had to show for the vast sums annually lavished on them for purposes often of very doubtful public utility. He hoped that no cheeseparing stingy legislation would ever arise to diminish the usefulness and impair the health of the body of which Sir Archibald Geikie had given them such an excellent account.

Mr. George Lewis (Derby) said he thought Sir Archibald Geikie

told them how they could bring some pressure to bear on the Education Department. Some little time ago, he was in the Ordnance office in London and had shown him some beautiful maps, which had been brought out by the German and Swiss governments and which he thought a distinct improvement on their own. They were coloured, and the colouring was most beautifully done, and he was also informed that they were produced at very much less cost than their own. As to the length of time before Ordnance and geological maps in colliery districts should be revised, the Ordnance authorities suggested ten years. He replied that five years was not too short an interval. If they could bring pressure to bear on the Government on the point it would be desirable.

The PRESIDENT was not sure but that there were two sides to the question; and, after some further remarks, the subject was remitted to the Council for consideration.

DISCUSSION ON MR. J. C. B. HENDY'S PAPER ON "EXPERIMENTS UPON A WADDLE FAN AND A CAPELL FAN WORKING ON THE SAME MINE AT EQUAL PERIPHERY SPEEDS AT TEVERSAL COLLIERY."*

Mr. M. DEACON (Alfreton) wrote that the position of the two fans with relation to the fan drift was somewhat in favour of the Waddle fan, which had practically a straight lead; whilst with the Capell fan, the air had to ascend a pit about 27 feet high and then turn at a right-angle to the inlet of the fan, and another portion of the air had to pass at the back of the mid-wall in the drift, upon which the fan-shaft bearing rested, and doubled round the end of the wall before reaching the fan. In the following experiments upon the fans at Teversal colliery, the air was measured in the fan-drift, in front of the mid-wall, and the drift (with an area of 78·54 square feet) was marked off into equal areas by means of strings. The velocity of the air was measured in each space for two minutes and the mean of the measurements taken as the velocity of the current. The water-gauge was fixed about 28 feet from the inlet of the Waddle fan, and 39 feet from the inlet of the Capell fan; and the orifices of both fans were in the same direction as the air-current. The Waddle fan is 30 feet in diameter, and the Capell fan is 16 feet in diameter. The following is a record of the tests:—

* *Trans. Fed. Inst.*, vol. iv., page 474.

Type of Fan.	Revolutions of Fan per Minute.	Periphery Speed of Fan per Second.	Mean Velocity of Air in Drift per Minute.	Water-gauge in Drift.	Water-gauge on Drift Door.	Volume of Air per Minute.	Manometric Efficiency With Water-gauge in Drift.	Manometric Efficiency With Water-gauge on Drift Door.	Horse-power in the Air.	Indicated Horse-power of Engine.	Mechanical Efficiency.
		Feet.	Feet.	Ins.	Ins.	Cubic Ft.	Per Cent.	Per Cent.			%
Waddle	71	111·5	1,406	1·95	2·15	110,427	34·3	37·8	33·9	70·9	47·8
Capell	132	110·5	1,430	1·95	2·20	112,312	34·9	39·4	34·5	59·4	58·0

He (Mr. Deacon) agreed with Mr. Capell in his conclusion that the manometric efficiency of a fan did not necessarily imply high mechanical efficiency. In support of this view, he gave the results observed on three fans at the Blackwell collieries; the water-gauges in each case being placed as nearly as possible in a similar position, viz.: 18 inches from the inlet of the fan. The results obtained at the periphery speed of 85½ feet per second are as follows:—

Type of Fan.	Diameter.		Width.		Inlet.	Manometric Efficiency.	Mechanical Efficiency.	Proportion of Output to Body Capacity.	Drift Water-gauge.
	Ft.	Ins.	Ft.	Ins.					Inches.
Guibal	45	3	11	7	Single	60·6	41·8	15·6	2·00
"	36	0	12	0	"	60·0	44·5	22·4	2·00
"	30	0	9	9	"	56·0	42·3	26·3	1·85
Walker-Guibal...	24	0	8	0	Double	66·6	51·8	42·9	2·20
Capell	12	6	5	8	Single	40·9	55·8	74·7	1·35

When the fans were running at their relative maximum safe speeds, the following results were obtained:—

Type of Fan.	Diameter.		Width.		Periphery Speed per Second.		Drift Water-gauge.	Manometric Efficiency.	Mechanical Efficiency.	Proportion of Output to Body Capacity.	Volume of Air per Minute.
	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Inches.	%	%	%	Cubic Feet.
Guibal ...	45	3	11	7	96	6	2·5	58·3	39·6	15·0	119,479
" ...	36	0	12	0	85	5	2·0	60·0	44·5	22·4	102,921
" ...	30	0	9	9	96	6	2·3	53·4	44·1	25·3	107,351
Walker-Guibal	24	0	8	0	85	5	2·2	66·6	51·8	42·9	105,016
Capell ...	12	6	5	8	141	1	3·8	42·7	68·5	83·0	123,186

From these results, it would appear that the proportion of output to body capacity bears an important relationship to the mechanical efficiency; the loss of mechanical efficiency being due in the case of the Guibal fans to the consumption of motive power in actuating a huge machine which is only capable of passing from 15 to 25 per cent. of its body capacity of air, while the Walker fan gives 43 per cent., and the Capell fan 75 to 83 per cent. This apparent defect in the Guibal fan is strikingly exhibited on

comparing the maximum speed results of the 45 feet Guibal fan and the 12½ feet Capell fan, the latter producing 123,000 cubic feet of air at 3·8 inches of water-gauge and the former 119,000 cubic feet of air at 2·5 inches of water-gauge. The low water-gauge of the Capell fan is difficult to account for, the same ratio existing for the high as for the low speeds, in proportion to the squares of the periphery speeds. From tests made upon the Capell fan, the Guibal fan, and the (5 feet) Schiele fan (working on the same mine as the Capell fan), he (Mr. Deacon) found that at equal periphery speeds (57 feet per second) the water-gauges were, Guibal fan, 0·87 inch; Capell fan, 0·55 inch; and Schiele fan, 0·22 inch; and that the periphery speeds of water-gauge required to produce 1 inch of water-gauge were respectively 60·3, 75·5, and 153 feet per second. These results appear to indicate that the water-gauges decline somewhat in proportion to the diameter of the fan and not in proportion to the squares of the periphery speeds. Natural ventilation cannot be considered a factor in these tests, as the temperatures in the upcast and downcast shafts were practically the same in each experiment, the tests being made when the surface temperature was nearly 80 degs. The low water-gauge of the Capell fan does not, however, appear to interfere with its economical work, since its mechanical efficiency is far in excess of that of the Guibal fans. This fact may be accounted for by the proportion of output to body capacity of the Capell fan being three or four times as great as that of the Guibal fans. Mr. A. L. Steavenson suggested* that the proper position of the water-gauge was at the pit-bottom. Its readings would not, however, then represent the work done by the fan in overcoming shaft-friction, assuming of course that the fan be not placed at the pit-bottom, a very rare occurrence; and if read in such a position, the mechanical efficiency of the fan could not be then obtained.

Mr. J. C. B. Hendy (Etherley) agreed with Mr. Deacon that the relative position of the two fans was against the Capell fan, and he had pointed out this fact in his paper. With reference to the further tests made by Mr. Deacon on these fans, he had hoped that the air would have been measured in the mine, instead of in the fan-drift. He considered, in the case of the Capell fan especially, that it was extremely difficult if not impossible to obtain reliable measurements in the fan-drift. The point where Mr. Deacon had chosen to measure the air would be 15 or 20 yards from the inlet of the Waddle fan, and closely adjacent to the inlet of the Capell fan, in front of the mid-wall and near to a sharp bend in the drift; and when the Capell fan was running, would be subject to local influences

* *Trans. Fed. Inst.*, vol. v., page 258.

and eddies, which would be entirely absent in the case of the Waddle fan. Mr. Deacon had made one experiment with each fan at the same water-gauge in the drift, viz.:—1·95 inches, and if these were compared with the average results of his (Mr. Hendy's) experiments, they would be found to be very similar. There was very little difference between the manometric efficiency and the volumes of air produced by the two fans. The mechanical efficiency of the Waddle fan was lower, being 47·8 as compared with 58 per cent. given by the Capell fan, but this difference would doubtless be due to the engine; the Waddle fan engine having been in constant use for twenty-five years, and the Capell fan engines were of recent erection. The results of Mr. Deacon's tests only confirmed him in the opinion he had before expressed, viz.:—That a modern Waddle fan working on the Teversal mine would give quite as good if not better results than the Capell fan. He was quite prepared to admit that this result might not be obtained in all cases, and that there might be exceptional cases or conditions favourable to the Capell fan which would allow of its yielding much better results. At the same time, it should be remembered that other fans have their favourable conditions, and there was consequently a considerable amount of difficulty and doubt as to the circumstances which ought to rule the adoption of any particular type of fan.

DISCUSSION ON MR. ARTHUR L. COLLINS' PAPER ON "FIRE-SETTING: THE ART OF MINING BY FIRE."*

Mr. J. B. Kirkup (Chester-le-Street) wrote that he had noticed Mr. M. Walton Brown's remarks on fire-setting in the discussion of Mr. Collins' paper. He happened to know the system mentioned, and the districts of Khamamett and Khondapilli well, and might say the gneiss of those places was particularly suitable for getting by fire. In the Khamamett district, the gneiss hills were of a dome-shape, rising out of the plain to heights of 200 or 300 feet, the surface being usually destitute of soil, and the rock very free from moisture. The bedding was fairly regular, and the partings from 1 foot to 2 feet apart. The first process was to make a slight cut on the edges of the desired block, as would be done if it were to be wedged, and afterwards to burn wood or dried cow-dung upon the rock until it broke loose. The Khondapilli stone did not show the dome shape, but was lying at sharper angles, and was got where the dip of the beds allowed fire to be applied. He had also noticed

* *Trans. Fed. Inst.*, vol. v., page 82.

slight exfoliation during the hot weather months, when the bare surface of these gneiss beds became too hot to be comfortable, if sat upon. The fire process had also undoubtedly been used by the ancients in the old workings of the gold-mines of Mysore and of the south-western Deccan; they must have possessed considerable skill in its use, as they attained depths varying from 250 to 300 feet on the quartz-vein. In opening out the old workings, remains of these charcoal fires were found upon the bottom floors of the mines.

Mr. ARTHUR L. COLLINS (London) wrote that the information brought out in the discussion as to the use of fire-setting for quarrying stone was of great interest, especially as the process had never come under his personal observation, and was overlooked in the original paper. He had recently had the opportunity of seeing the process as applied to mining in use in several places in Afghanistan, among which he might specially mention the Chilan lead-mines, about 50 miles north-west of Kabul. Here galena is found in veins generally only a few inches in width, in hard siliceous slates and grits, and the only tools known to the Hazara miners being the hammer and pointed chisel ("gad"); their progress is often absolutely barred unless fire be resorted to. The mines are situated at an elevation of nearly 10,000 feet above sea-level, in a treeless region, and the only fuel obtainable is a small prickly bush which is common on the stony mountain sides; and which burns so quickly that it has to be continually replenished. The workings gradually assume an upward slope, and are abandoned as soon as the vein becomes barren in this direction; a series of narrow irregular openings, little better than rabbit-burrows, being thus produced. The objections to a more extended use of the process are:—The scarcity of fuel, and the heat and smoke in the mine; all products of combustion having to find an outlet by the same tortuous channel, often less than 3 square feet in section, by which the men enter. Altogether, fire-setting as used in Afghanistan presents few points worthy of imitation by the modern miner.

The following paper, by Mr. Henry Aitken on "The Hilderston Silver-mine, near Linlithgow," was taken as read:—

THE HILDERSTON SILVER-MINE, NEAR LINLITHGOW.

BY HENRY AITKEN.

This mine is situated about four miles to the south of Linlithgow. The geological position is immediately above and in the mountain limestone, which is the base of the Under Coal Formation in Scotland, although one or two coal-seams are found below this point.

In Sibbald's Supplement to his *Prodromus*, MS. 33. 5. 19, Advocates' Library, Edinburgh, there is "Ane account of the Silver Myne at Hilderston Hills," given in the following terms:—

The mine was found by a collier nam'd Sandy Mund who found a heavie piece of Red Metal as he digg'd near to ye water of Hilderstoun. it was raced with many small strings like to hairs or thredds. it had descended from a vein thereof, where it had engender'd with the sparr stone. he found likewise a piece of Brownish sparr stone, which was massie. He brock it with his mattock and it was white and glittered within like unto small white copper Keese which tryed proved a rich ore. Mr. Atkinson who wrought this myne sayeth that it grew like the Hair of a man's head and ye grass in the field, and that the vein he found was once two inches thick by measure, the metal thereof was both malliable and tough, it was course silver worth 4 shillings 6 pence the ounce weight, not so fyne as the refined. the greatest plenty was found in the shaft called God's Blessing, out of the Red Metal and ye purest sort thereof then contained in it 24 ounces of fyne silver upon every hundredth weight, valued at 6 score pounds sterling the tun, and much of ye same red metal by essay held twelve score pound sterling per tun.

But when the mynes became the King's and were wrought by his order, it was not then so rich in silver, two scots ships at the 2d Return were fraighted therewith viz. the white sparr and ye Red metal togither, which at depth proved not so rich as the other before brought in one ship. When Atkinson wrought on the first sort of Red metal for Mr. Bulmer and the Lord Advocate of Scotland he sundry tymes refined it and commonly for the space of three days weekly he made 100 lb. sterling each day.

Bot when the Red metal was brought to London to be tried, smal profit did arise from it and scantly it payed charges of coals, and wages which were dear ther.

Bot Mr. Atkinson did in Scotland with peats and stone-coals at a reasonable price and did more in Scotland in one day than he could doe in three in London and with profit.

the Red metall till it came to 12 fathoms deep remained good, but from thence unto 30 fathoms deep it proved nought it was quite altered in quality, but not in colour, fashion and heaviness.

And in Sibbald's *Description of Scotland*, MS. 15. 1. 1, Advocates' Library, Edinburgh, there is "Ane Account of the Gold and Silver found in Scotland out of Lex Mercatoria, 2 part, 2 chapter," in which it is stated:—

That Mine in Scotland which lyeth in the grounds of Sir Thomas Hamilton, Knight, Lord Advocate of Scotland, discovered in the year 1607 by means of a collier, in the report of the goodnesse of this mine hath been very great diversity, acording as they found the ore of the severall veins, for the Blossome of silver ore, or the small veins, cannot give true directions of the riches of the mines, for which cause the Spaniards in the West Indies, having found any vein of a myne, they will persue the same towards the East, and seek to find out as it were the trunk or body of the trie which they call Beta, saying—e menester siempre buscar la Beta de la minà—we must alwayes seek after the Body of the mine, which may be sometyme three or four foot broad, when the veins are like ane arme or finger. Some trialls of this did report 80 lb. of Silver in 100 weight, other 60 lb., 40 lb., 35 lb., and 20 lb., then it fell into ounces, which was more reasonable and naturall.

By the Kings order ten tuns of the said silver ore was brought into the tour of London, whereof one tun of 2000 lb. weight was indifferently taken and calcined or grinded togither, and thereunto were two tuns of Lead added, commixed and afterwards molten by a continual fire and hand-blast of foure men, and ther was a cake of silver remaining, weighing 17½ ounces, and the extraction out of the Lead was some four or fyve ounces more, so it was reported to be 22 ounces in the 100 weight of ore, but the charge was great.

ther was other tryalls by William Beal with a far lesse quantity of Lead and roasting the oar, and by Mr. Broad and Mr. Russel who refined the same with the flag of Lead, others by lead ore to save the charges, and they all found above 22 ounces of silver in the 100 weight of ore. The Portugal tryall with Quicksilver found 23 or 24 ounces, and some 20 lb. weight being sent beyond sea, grinded, shadered, and washed, to ane expert mint master, he found upon his first tryall 42 ounces and of the others lesse, and said the oar was easie to be wrought (but by other means) and with little charges, and that the maner to refine by quicksilver was good for poore mines of 2 or 3 ounces wher the ore had litle or no lead and that the commixture of the mine was very britle.

In August 1609, 400 barrells of the ore was brought to the tour and upon tryall by Mr. Broad 29 ounces was found of ane 100 in ore and 24 lb. the ton was offered for it but refused.

Atkinson in the year 1619, wrote a notice of "The Discoverie and Historie of the Gold Mines in Scotland" (Bannatyne Club, 1835), in which he says:—

Sir Bevis Bulmer hath sett downe in his booke, the manner how the rich silver Mynes at Hilderstone in Scotland were found; and how they were lost, &c. After the full discovery thereof he rested not untill he named them, calling one pitte or shafte there, God's Blessing, because of the wonderfull works of God, that he had seene which never before the like thereunto within any of His Majesty's Kingdoms (were) knowne to be. And I have good cause to be well acquainted with that Silver Myne, being there imployed from the begininge till the going out thereof, as a refiner of the same, and a longer time than any others of England, Scotland, or Germany.

Now, concerning the first finding thereof, Sir Bevis saithe in his booke, that it

was found out by meere fortune or chance of a collier, by name Sandy Maund, a Scotsman, as he sought about the skirts of those hills neere to the bourne or water of Hilderstone. And this Scotsman, by means of digging the ground, hitt upon the heavy peece of redd mettle; no man thereabouts ever saw the like. It was raced with many small stringes, like unto haiers or thredds. It had descended from a vaine thereof, where it had engendered with the sparr-stone, which sparr-stone in forraine provinces is called by other travellers cacilla. And he sought further into the ground, and found a piece of brounish sparr-stone, and it was mossie. He broke it with his mattocke, and it was white, and glittered within, like unto small white copper keese, which is to be found in many common free-stones. And he never dreamed of any silver to be in that stone, and he showed it to some of his freinds; and they said, "Where hadst thou it?" Quoth he, "At the Silver bourne, under the hill called Kerne-Popple." Whereupon a gent of Lythcoo, wished Sandy Maund to travaille unto the Lead-hill, and about Glangonner water he should hear of one Sir Bevis Bulmer, and said, "If it prove good he will be thankefull, if otherwise he will reward thee; and I will send to him my letter; (and) if he doe not, I will." Whereupon, he tooke his journey towards the Leadhill, and came to Mr. Bulmer's house, and shewed these few mineralls, or minerall stones that he had gotten at the Silver bourne near to Lythcoo; and gave him a letter from Mr. Robert Steward, which was lovingly accepted of; and then one of his servants made fier in the assay-furnace to make triall thereof. Mr. Bulmer did not trust to the first triall, because it proved riche; but went to it againe, and againe, and still it proved rich and wonderous rich. But thereof will I write at large hereafter; and till then proceed (with) what I have (read), or found after my coming to God's Blessing in Scotland.

Shortly after I was brought thither, the silver myne being sett open, I was stricken downe into the shaft called God's Blessing; and I brought up with me a most admirable peece of the cacilla stone, a minerall stone, which me thought came from one of God's treasure houses; part whereof I kept still, and a part thereof I sent for a token unto London to my uncle Atkinson of Foster Lane, and it was much accepted of. It was much more admired (at) by many goldsmiths of London who saw it, proved it, tryed and commended (it) above all others that ever they saw before.

And then my uncle Atkinson, who now is dead, he made an occasion, and went to the Court at Whitehall, desirous to speake with the Earle of Salisbury, his honourable good lord and freind, unto whome he shewed it. And the Earl of Salisbury admired at (it), saying, "Mr. Atkinson, you have don me as great a pleasure herein, and more than I expected, or could devise; if so be that it be gotten within the Kingdom of Scotland, without collusion; for I must tell you, there be many prodigious workemen in the worlde; and too many in the Kingdom of England." Whereupon Mr. Atkinson replied, saying, "My Lord, I will hasserd my life that this token sent to me by my kinsman, was gotten by him in the ground. I dare presume thereof; for hitherto, I thanke God, I have brought him up from his cradle, and I am sure he doth not collude." And then the Earle replied, saying, "Shall I then believe you? and may I shew it unto the King's Majesty? I tell you trewly it is the best token that ever I received out of that kingdom, or any other kingdom of that quality, by any other gent whatsoever; and I will be thankfull unto you, use me when you please." And the Earle said, "A more curious peece of worke in a stone (viz.) in a minerall or minerall-stone, no man hath ever seene; which I esteeme above all others, because of Scotland, from whence I have had sundry times gold, but never anything in this sorte as perfitt silver." Further promising Mr. Atkinson that he would shew it unto the kinge, and deliver it againe if he be not countermanded. But it was never more seene to Mr. Atkinson, neither had he ever content for it.

The manner how it grew was like unto the haire of a man's head, and the grasse in the feilde. And the vaine thereof, out of which I had it, was once two inches thick, by measure and rule: the mettle thereof was both malliable and toughe. It was course silver, worth 4s. vid. the ounce weight; not fine silver as is made by the art of man.

The greatest quantity of silver that ever was gotten at God's Blessing was raised and fined out of the red-mettle; and the purest sort thereof then conteyned in it 24 ounce of fine silver upon every hundred weight; vallewed at vi score pounds starling the ton. And much of the same redd-mettle, by the assay, held twelve score pounds starling per ton weight. But when the same Mines befell unto the King's Majesty to be superiour or gouvernour thereof, then indeede it was not so rich in silver altogeather. But two Scotts shipps, at the second retourne, were fraighted therewith (vizt.) the white sparr and the redd-mettle togeather; which at depth proved not so rich as the other before brought in one shipp, in the last long great frost, &c., unto the Tower of London, wherof I will hereafter speake at large, for I was in the shipp.

And when I wrought on the first sorte of redd-mettle for Mr. Bulmer and my Lord Advocate of Scotland, sundry times I refined it; and commonly for the space of three dayes weekly I made an hundred (pounds) starling each day, &c. Some parte of the same redd-mettle was brought to London to be tryed, and small profit arose thereof; and scantly it paid charges thereof: for the Blessing of God was extracted by God's Providence before I tryed of the like redd-mettle at the Tower of London, being a parcel of the first ten tons; and coales and other charges were so dere, as wages, &c., so as it scantly countervaled the expences thereof. But in Scotland it was done by me with peates and stone coles at reasonable price, &c.; and I did more in Scotland in one day than in three at London. Thereby came profitt. But this was the strangest of all others, and as it were almost incredible for man to believe (vizt.) Untill the same redd-mettle came unto 12 faddomes deepe, it remained still good; from thence unto 30 fathome deepe it proved nought: the property thereof was quite changed miraculously in goodnes; it was worth little or nothing; and more, uppon an instant, after the Bronswicks entered, it was quite altered in quality, but not in colour, fashion, and heaviness.

And thus much more, I dare presume to promise, with the help of God's assistance, and his Majesty's lawdable authority, to discover the like silver Myne neere unto Hilderstone, as was before at Hilderstone, having the helpe of an Englishman named before in my commission for the gold Mynes, which hardly will be effected, but only for his gracious Majesty. And how long then the same will continue, being discovered, that is best known unto God, not to any man, &c.: for Mynes be as uncertain for continuance, as life is to man, which is like a bubble of water upon the waters; to-day a man, to-morrow none.

About 1865, an effort was made to reopen the mine but difficulties with water being considerable, the work was stopped.

About 1870, work was resumed and engines erected, levels driven to take off the surface water from the limestone quarries, which are of considerable extent, and a vertical shaft was sunk to a depth of over 220 feet. This shaft went considerably below the workings of the ancients.

The vein lies on a whinstone dyke, which runs nearly east and west, with a dip to the south. This whin dyke is a branch or arm from a whin dyke to the west running nearly north and south. A little to the

east of No. 2 pit, the branch whin dyke dies out entirely, and is represented in the limestone to the east by a small fault or hitch with a little spar in it, but no ore.

The strata forming the hanging wall of the vein measured vertically are:—

	Ft.	In.
Surface, clay, stones	18	0
Sandstone	11	0
Fakes	87	0
Whinstone	16	0
Blaes	11	0
Limestone	54	0
Marl	42	0
Marl and whin	36	0
Total	225	0

Near the bottom of the pit, the vein almost entirely vanished. A borehole was put down to a depth of 360 feet below the metals found in the bottom of the pit, but proved almost nothing except marl.

In none of the modern workings has silver been discovered, the former workers having apparently exhausted the mine near the surface, and the vein proved unproductive in depth.

The exploration of the old waste proved that the ancients had worked nearly all out to a depth of about 60 feet, refilling the waste with the refuse rock, nearly all of which was baryta. In this waste a considerable quantity of nickel ore was found, but as it was nearly all oxidized to a powder it was difficult to collect. In the unoxidized state the ore was an arsenious sulphuret of nickel, containing about 30 per cent. of nickel and 2 per cent. of cobalt. The value of nickel ore was not known to the ancients. No native silver or galena was found.

The vein opposite the whinstone was about 6 feet wide and consisted entirely of baryta. Opposite the blaes, the vein carried baryta, and very little galena without any silver in it; opposite the limestone, baryta and a very little nickel ore and galena with a little silver in it were found. When the vein came to the marl, it practically disappeared. The whinstone carried stringers of spar, but no ore could be seen of any kind. Various mines were driven and many surface-ditches cut, but nothing obtained of any value.

About 60 yards to the north there is a thin vein which carries a little galena, but not of any value.

The works were abandoned in 1873, and nothing has since been done. Judging by the ancient records, native silver has been worked in this

mine. If so, so far as the writer knows, this is the only place in Scotland where native silver has been worked. Silver lead, notwithstanding the low prices of both these metals, is still being worked at Wanlockhead and Leadhills. At several places in Scotland, lead ores have been found and worked, but at present the last-named mines are the only two so far as the writer is aware, working ore.

Nickel ore was worked at one time in Argyleshire, but nothing has been done at these mines for many years. Nickel ore is also said to have been worked in the Ochil hills.

Some tools of the old workers were found in the workings very much the same as those now in use.

Lime seems to have been used by the old workers for bursting the rock, as one jumper hole was found full of lime.

The following paper by Mr. John Morison on "Limestone Mining in Scotland" was taken as read:—

LIMESTONE MINING IN SCOTLAND.

BY JOHN MORISON.

INTRODUCTION.

Mining of limestone in Scotland has been carried on for many years in the thinner beds of the Carboniferous Limestone, and in the Burdiehouse limestone in the Calciferous Sandstone formation. In the latter bed, the writer is informed that mining in preference to opencast or quarrying has been carried on for upwards of eighty years.

Although, as will be seen from the descriptions of the working of mines which have been selected as typical of the systems pursued, very little new information from a mining point of view can be gathered, it has been represented to the author that a description of the working of limestone by mining would prove interesting to members from districts where opencast working of limestone is the usual method of working adopted.

The selection of the method of working any bed will obviously be influenced in the first instance by the relative thickness of the workable bed of limestone to the thickness of the "tirring" or unworkable material above it which would have to be removed if the stone were worked opencast; but the general adoption of mining in preference to quarrying in Scotland is probably due to the beds of pure or workable limestone being comparatively thin, say from 6 to 16 or 18 feet. It is, however, probable that under conditions favourable for mining the stone may be wrought as cheaply and as safely by mining as by quarrying, unless the quarry has very much less covering or tirring than is usually found.

The conditions favourable to mining may be summarized as follows:— 1, a strong roof; 2, a soft bed of material other than limestone for holing or kirving; 3, the presence of "backs and cutters" or fractures in the stone.

The presence of a good roof is absolutely essential to successful mining, but the absence of the other conditions may be compensated for by sufficient thickness of good stone, and in many instances it is necessary to leave part of the limestone itself to form a good roof.

The total quantity of limestone mined in the East of Scotland during the year 1892 was 277,598 tons, and during the same year there were two fatal accidents, and three non-fatal accidents causing serious personal injury. The number of persons employed underground for this output and for an additional output of 2,022 tons of metallic ore was 500.

The workings described in the paper are:—The Leavenseat mines, worked by Messrs. P. Mitchell & Son; the Burdiehouse mines, worked by Sir D. Baird, Bart.; and the D'Arcy mines, worked by the Lothian Coal Co., Ltd.

The writer is indebted to Messrs. Mitchell & Son, and to Mr. D. Webster, manager for Sir D. Baird, for particulars of the Leavenseat and Burdiehouse mines.

Leavenseat Mines.

The limestone has the following section:—

Cover, 18 fathoms. Freestone roof.

	Ft.	Ins.	Ft.	Ins.
Blaes	1	0		
Shale	1	0		
Blaes parting	0	1½		
Top stone	5	3		
Blaes parting	0	1½		
Blue stone	1	11		
Blaes pavement		—		
			9	5

Of which 7 feet 2 inches is good stone.

The shale is of some value, as it contains 31·87 gallons of crude oil per ton.

The method of working is as follows:—The blaes and shale is holed to a distance of about 3 or 4 yards, the shale being separated. After the holing is finished, holes are drilled in the 1½ inches parting with ratchet-drills and the top-stone is blown up. The bottom-stone is usually left on for some distance and it is blown up by drilling holes through it and blasting with powder or gelatine-dynamite, the latter being the principal explosive used. The places are driven 6 yards wide, and stoops 6 yards square are left in.

Wagons carrying about 30 cwts. of stone are taken into the face.

The inclination of the seam is 1 in 12. There are cutters about 4 feet apart which assist materially in the blasting of the stone, but very few backs.

The bed worked is, the writer believes, the No. 6 limestone at the base of the Millstone Grit.

Burdiehouse Mines.

The bed of limestone worked at these mines is of a peculiar nature and is considered by some authorities to be a fresh-water deposit. Dr. Hibbert's conclusions in support of this theory are based on two facts:—

1, the entire absence of marine shells and corals; 2, the presence of thousands of fresh-water plants, which are in most cases so entire and perfect as to render it improbable that they were borne by rivers and torrents from a distance and subjected to the chafing of the tide. Mr. Charles McLaren in his *Geology of Fife and the Lothians* appears to incline to the opinion that the Burdiehouse limestone is a marine deposit.

The deposit as worked is 28 feet thick. The system of working is as follows:—Following the dip of the seam from the outcrop at an inclination of 1 in 3, a "dook" is driven down in the seam, 15 feet wide. Three feet of the limestone is left to form a roof, leaving the working 25 feet high. From the dook, levels are turned off right-and-left every 24 yards, and are driven 15 feet wide. The stone is worked by holing in the uppermost working bed which is 5½ feet thick, and of which 4 feet is holed out, the remaining 1 foot 6 inches being afterwards dropped, and this is done entirely by blasting, the stone being too strong to admit of working with picks. The holers are kept well in advance of the miners behind, and throw their material back over the ledge of the lower limestone where it is filled by the men behind into wagons. There is no refuse, the seam being perfectly clean. The holers use single hand-drills, and drill their holes 1¼ inches in diameter by about 3 feet 6 inches deep. The explosive used is gunpowder. The holers are paid by the superficial yard of stone bared and the remainder of the workmen are paid datal wages. When the holing is completed and well in advance, the remainder of the stone is worked in exactly the same manner as an open quarry.

Stoops are left in from 12 feet to 18 feet square, or sometimes oblong and of irregular shape, and no fixed size appears to be adopted, or to be necessary. No timber whatever is used for supporting the roof. The depth from the surface at the extreme dip is now about 40 fathoms.

Wagons carrying 18 cwts. of stone are run by a main-rope engine down the incline, and sidings are laid in the various levels, from which the men run the wagons to the working-places. The stone from two places to the rise, *i.e.*, for a distance of 24 yards, slides down to the level below, where it is filled into the wagons.

The following is a section of the working:—

Roof, 3 feet, good limestone.

	Ft.	Ins.	Ft.	Ins.
Good limestone	1	6		
" (holing)	4	0		
"	7	0		
"	8	6		
"	4	0		
			25	0

There are distinct partings of black carbonaceous matter between the various beds, and the beds vary in colour from a light cream to a slaty blue.

The ventilation is natural, and appears to be quite sufficient to keep the workings clean, although a considerable quantity of powder is used daily.

D'Arcy Mines.

The bed of stone worked is the No. 1 limestone of the Carboniferous Limestone, and it marks the base of the workable coal-seams of that series.

The bed is won by an adit-drift, and the depth from the surface to the workings is about 22 fathoms. The following is a section of the superincumbent strata:—

	Ft.	Ins.	Ft.	Ins.
1. Surface soil	3	0		
2. Blaes and limestone	6	0		
3. Blaes	2	0		
4. Limestone	6	0		
5. Blaes and limestone	98	0		
6. Hard blaes	6	0		
7. Limestone	2	6		
			123	6

Nos. 2 and 4 beds have been worked to some extent opencast, but are of inferior quality. No. 5 is a series of thin irregular bands of limestone mixed with blaes.

The inclination of the seam is 1 in 5. A section of the working is as follows:—

Roof, limestone, 2 feet 6 inches.

	Ft.	Ins.	Ft.	Ins.
Limestone	1	0		
Parting	0	1½		
Limestone	2	0		
Parting	0	1½		
Limestone	1	0		
Band	0	4		
Limestone	0	9		
"	1	5		
"	2	6		
Coarse limestone	1	6		
Holing blaes	3	0		
			13	9

The working is stoop-and-room, the level-course being about east and west. The stoops are left in 6 yards by 6 yards. The width of the places is varied according to the condition of the roof, but the places are usually driven about 6 yards wide. In some instances, double this width has been driven without danger.

The seam is characterized by very marked backs or fractures running across the level-course, and by less marked cutters running level-course. The backs are frequently open to the extent of about 12 inches and filled with clay, which has washed down from the surface. The backs and cutters are of material assistance in working the stone, but are a source of danger, and when they extend through the roof-stone, frequently require to be wedged with timber to prevent part of the roof from dropping in.

In working, the bottom blaes is taken out by blasting with gelatine-dynamite, the holes being drilled to a depth of 6 feet by ratchet-drills. The bottom-stone is then drilled at the parting to a depth of 3½ to 4½ feet, and a heavy charge of powder (2 to 3 lbs.) is fired. Usually the stone does not come down with the first charge, and if not, the hole is recharged and fired, and the stone comes down. It is probably worthy of note that the miners seem to consider it advantageous not to bring the stone down with the first charge, as the second charge appears to work to more advantage owing to the shock of the first charge.

A similar method is pursued with the bed above, and the upper-stone, below the roof-stone, which is invariably left untouched, is left on until the stoop is formed, when it comes down more easily and in larger quantities. In bringing the top-stone down, the principle of firing the same hole with charges insufficient to bring it down in the first instance is adopted, the same hole, about 3 feet deep, being fired sometimes three times with ½ lb., 1 lb., and then 1½ lbs. of powder.

The limestone is conveyed from the faces to the kilns by hutches, carrying 10 cwts. of stone, the hutches being taken to the rise-places by self-acting inclines, and along the level by horses.

Ventilation is effected by a furnace in summer, and by natural means in winter.

It may be useful to mention that the quantity of stone turned out per man per day from some of the mines referred to in this paper amounts to 4 tons per man employed at the working-face, a quantity which will probably compare favourably with a good quarry.

The following paper by Mr. A. C. G. Cameron on the "Geology, Mining, and Economic Uses of Fullers' Earth" was taken as read:—

Excellent beds of fullers' earth occasionally occur in the Lower Greensand, and that of Bedfordshire may be taken as an illustration.

A great deal of the fullers' earth of commerce comes at present from Woburn Sands, on the borders of Bedfordshire and Buckinghamshire. It appears also that at one time it was dug where the Lower Greensand comes to the surface in the eastern part of Hampshire,* "Bedfordshire and Hampshire being the only two places mentioned by most authors where fullers' earth is found."† No reference is made by Mr. Sowerby to the well-known earth-pits at Ryegate and Nutfield in Surrey.

Perhaps the earliest reference to the Woburn earth is in the *Philosophical Transactions* for 1684, which says "there is fullers' earth of a yellowish colour at Wavendon, near Woburn." Later on in the *Philosophical Transactions*,‡ there is a description of the "pits for fullers' earth in Bedfordshire." This exceedingly interesting account is contained in a letter (dated Bedford, 1723) from the Rev. Mr. Holloway to the celebrated Dr. Woodward, who, it is elsewhere stated, had a very high opinion of fullers' earth. From Mr. Holloway's letter, we learn that the workmen seldom undermined the ground, but dug away the earth below, while others were employed carrying off the surface; the reason being, continues the memoir—

"that the matter above being of so light and flitting a nature would fall in and endanger the workmen, for the stratum of sandstone which occurs before they come to the fullers' earth does not lie, as in coal-pits, immediately over the matter they dig for, like a ceiling, but even in the midst of the superjacent strata of sand, and therefore can be no security to them if they undermine them."

As we approach the early part of the present century, we find Messrs. Phillips and Conybeare in 1822 writing of fullers' earth as "having been extensively dug in Bedfordshire," also that "not one of the three fullers' earth pits now working at Nutfield§ are open to the bottom of the fullers' earth," implying, seemingly, that at the time of their visit there was no great call for this mineral. The old cloth trade, which had been at its zenith, was beginning to decline then, and consequently a falling off in fullers' earth works was setting in.

Nothing in particular has been written about fullers' earth since these authors' time, although analyses of the mineral from various districts

* "The Clays of Hampshire," by Mr. T. W. Shore, F.G.S., *Hants Field Club*, 1890.

† Sowerby's *Mineralogy*, 1809, vol. iii., page 59.

‡ Vol. vi., 1713-23, page 674.

§ For Nutfield, see "Geology of the Weald," Memoir, *Geological Survey*, by Mr. W. Topley.

have been published. Recently, papers have begun to appear again, more particularly, on the fullers' earth of Hampshire, Bedfordshire, and Surrey.*

Woburn earth is of the best quality and justly held in high repute. The Lower Greensand attains its greatest thickness and elevation at Woburn Sands, and being diversified with moors and thickly wooded hollows gives rise to very pleasing scenery. The escarpment juts considerably forward there, rising high above the plain of Oxford Clay to the north, making a striking feature in the landscape. From the railway station in the plain below, can be descried, perched on an eminence, the recently erected works of the Fullers' Earth Mining Company, Limited, an incline down the steep hill-side connecting with a working shaft to the mine below.

The British Fullers' Earth Company, Limited, have also a shaft hidden away almost, in an adjacent hollow, so suddenly does it come to view. This company's works adjoin the railway station, so that the seclusion of this little mine is most complete.

Although fullers' earth has now been known on the borders of Bedfordshire and Buckinghamshire for more than 200 years, it was only in 1890, that mining on systematic principles became established, and the writer believes it is the only instance at the present time where mining for fullers' earth (in the sense of underground galleries timbered and propped) is carried on.

Previous to the Fullers' Earth Mining Co. entering upon their royalty, the people around Woburn dug the fullers' earth in a desultory sort of way for their own use, or to supply dealers who came round when there was any call for it. Not more than one of these earth-wells, or simply wells, as they are frequently called, was open in 1890. This method of procuring the fullers' earth resulted in cylindrical holes being dug, without lining of any sort, to considerable depths in the sands, the earth being sent up to bank in a bucket by means of extremely primitive looking machinery. Before the close of 1891, there were kilns erected for drying, and mills used in the preparation of the earth, while little waggons with their loads of mineral were gliding up the steep hill-side, now an industry giving employment to some hundred men.

Although it is all one sort of earth at Woburn, the beds alternate in colour downwards, from yellow, through blue, to yellow again, the parti-

* "The Clays of Hampshire," by Mr. T. W. Shore, F.G.S., *Hants Field Club*, 1890. "Hampshire Fullers' Earth," by Mr. J. Brierley," *Hants Field Club*, 1891. "Bedfordshire Fullers' Earth," by Mr. A. C. G. Cameron, *Brit. Assoc.*, 1885; *Geol. Assoc.*, 1892, vol. xii. "Bath (Midford) Refining Works," Bath Society Paper, March 16, 1887.

colouring being more due to watery infiltration, causing oxidation of the iron-salts that gives the bluish colour, than to a greater or less proximity of the beds to atmospheric influences.

Mr. Player, of London, who has analyzed the Woburn earth, says with reference to these alternations that the difference in colour does not seem to be explained by difference in composition. The divisional lines are not constant, however, whatever the nature of the change may be. Even over the moderate distance to which this mineral is known, there is considerable disparity, and it is only in its greater development that it can be said to be divided into three parts. Elsewhere, the blue earth tails off amidst the yellow, and the yellow in turn may soon split up and thin away amongst the sand. Opinions differ as to which earth is the best; those who use the yellow refusing to have anything to do with the blue, and *vice versa*. For particular purposes, however, as fulling for instance, the blue earth is frequently of as good a quality as the yellow.

Woburn earth is less calcareous than that of Bath, as might be expected from the nature of the enclosing beds. For the same reason there is more iron in the fullers' earth of Bedfordshire and Surrey than is found in that of Gloucestershire. Fossils are extremely scarce in the Woburn earth—or indeed extraneous matter of any sort. Only a single specimen has been found of those nodular masses of sulphate of barytes (heavy spar) which are frequent in the beds at Nutfield.

Viewed broadly, the deposit of fullers' earth near Woburn is a tabular lenticular mass, lying well down in the sand, and outcropping on the face of the escarpment. While seeming to be fairly horizontal, the planes of bedding in the underground galleries—through which, by the courtesy of the managers, the writer has frequently been led, show undulating ridges and furrows, the material having adapted itself originally to irregularities and hollows in a sea-bottom.* It is well worthy of note that in the floor of these mines there is a white and sometimes green sandstone, a variety of which, with a glassy texture, built into the tower of a neighbouring church, has been recognized as like some that occurs in the Lower Greensand of Ightham, in Kent. Until quite the other day the white stone outcropped round an eminence adjoining the mines, but the place is now built upon. This appears to be the stone referred to by the Rev. Mr. Holloway in his letter of 1723, to Dr. Woodward.†

* When the Geologists' Association visited these mines in June, 1892, the managers met the members and showed them the underground galleries, extending to many hundreds of feet. Through the foresight of the managers the mines had been suitably prepared, being beautifully illuminated by numerous candles placed at convenient intervals.

† Messrs. Phillips and Conybeare, page 138.

There are no very copious springs near Woburn, as is the case in the deep valleys around Bath. Nevertheless the Woburn earth is an important bed. The water retained by this clay is exceedingly pure, and blocks of the clay have been put in some wells to purify the water. In dry seasons dealers carry the earth to the fen districts to clarify the peaty water, almost the only water-supply available in those parts of England.

The writer can conceive of fullers' earth being a very useful substance in clarifying and removing organic matter in solution, besides reducing the hardness and otherwise altering the character of the water. It might be found useful in getting over the question of sewage water. Mr. Dames of the Fullers' Earth Mining Co. tells me that the calcareous incrustations, so destructive to boilers, are carried down and disappear under the influence of fullers' earth. Woburn earth, when dried, splits and breaks into pieces of all angles and sizes. It is very moist, however, when fresh dug.

Mr. Player tells me that the volatile matter (presumably water) is retained with much tenacity, a bright red heat being required to get rid of it all.

Besides being used in the fulling-mills, the Woburn earth is now successfully applied to other uses. It is to the detergent properties of this mineral that the lard made from the American cottonseed oil owes its beautiful white colour. The artificial preparation of ultramarine, paper-making, the extraction of grease spots from wallpapers, scouring butter-boards, hearthstones, and the like, are all facilitated by the use of fullers' earth. Therapeutically, it is an absorbent of no mean power, and its cooling and healing properties must not be overlooked. It is even swallowed and taken as snuff.

This isolated deposit of fullers' earth is sufficiently interesting from a geological point of view, apart from its being a source of economic wealth to the district.

We must hope that some day it will be found in other parts of the same ridge of sand hills, seeing that a great deal of the sand is concealed by drift.

The following paper by Mr. H. Aitken on "The Formation of the Earth's Crust and its Destruction" was taken as read :—

THE FORMATION OF THE EARTH'S CRUST AND ITS DESTRUCTION.

BY HENRY AITKEN.

For many years the writer has been convinced that the presently accepted ideas as to how the so-called sedimentary rocks were formed are incorrect. He has for a very long time past promised the Secretary of the Mining Institute of Scotland a paper on this subject, but the work to be done by the microscope and analysis is so enormous that it would take years of constant study and observation to fully work out even the fringe of the matter. The writer is thus forced to content himself by recording in the shortest manner possible the bare idea, leaving it to others with more time to follow on.

Broadly speaking, the usually accepted idea is that the sedimentary rocks are the solid matter of earlier formations washed into their present position; but the writer is convinced that this idea is entirely wrong, except in very few cases, such as rocks of a conglomerate nature. The writer holds that the washed-in theory is wrong, because it is impossible that the rocks could have been so formed; and in order that he may be understood, he will take the Scotch coal-field as an example.

The Scotch coal-field, as it now is, may be said to extend over an area of 80 by 30 miles, with breaks. When formed, it must have extended very greatly beyond its present area, but, even as it now exists, it is sufficiently large for the purposes of illustration. The greatest depth of this coal-basin may be taken at 4,000 feet.

The present theory is that all sandstones, shales, etc., in this depth of material were washed-in as solid particles from the decayed rocks of earlier formation. This is simply a natural impossibility, if the laws of nature were the same when the coal-seams were formed as they now are. Take as an illustration the action that now goes on when a river or burn runs into a loch. All the sand and stones are deposited where the river enters, and the finer material, mud, etc., are floated farther into the loch. But in the coal-formation sandstones, shales, etc., are found spread irregularly over the whole area. The sandstones, etc., as a rule, keep their character according to their position in the strata, and the same remark equally applies to nearly all the other rocks. These beds are indeed so regular that the miner takes as his "landmarks" the nature of the sandstone, or some bed of shale or some rib of stone, often only 1 inch thick, to indicate the geological position.

It is well known that in the Scotch coal-field there are many thin ribs of stone of peculiar character which indicate the geological position of the strata; there are many beds of shells spread over the whole area, and beds of limestone, each of different character. It seems impossible that these thin or thick beds of shells, limestones, etc., could be washed in over such an area and spread out as they have been by the action of water, and that all the different materials have been selected and "binged" at different times, ready to be washed into place.

An examination of the particles of the sand composing the sandstones does not show any washed or water-worn signs. Indeed, all through the coal-formation there is an almost entire want of any evidence of the active wash of water. The writer knows of only one or two instances where it is certain that there has been any active washing away by water of deposited strata, and in these cases the areas affected were small.

The question then arises how these deposits were made as they now are, and the answer is that the whole, excepting the igneous rocks, were deposited from water by micro-organisms—or as the writer prefers to call them "selectors"—which had the power of selecting from the waters what was in them, and depositing them in many cases—these selectors forming in part the strata.

It is now generally conceded that limestones are not washed-in deposits, but built *in situ* by animal life or selectors. The ironstones, clay and black-bands were formed in like manner, and the making of limestone and iron-ore are both proceeding to this day by selectors. The coal-seams were similar deposits *in situ*. As to the beds of shale and shells these "grew" where they are. Why should a different rule apply to sandstones, etc.?

It seems clear that under the same waters, coal, ironstone, sandstone, shale, etc., were formed at one and the same time. As an illustration, a seam of coal might be taken. At one point it is common coal, at another it is cannel coal, farther on it is black-band ironstone, and at a more distant point common coal is found again; all these changes taking place in an area of less than half a square mile. Again a seam of common coal becomes filled with ribs of sandstone or shale, and farther on all becomes common coal again. Sometimes a piece of angular sandstone is found in a seam of common coal, and sometimes the sandstone takes the shape of a branch of a tree.

How does sandstone so occur? Simply by the action of the selectors, which, taking the silica from the waters, deposit it and at the same time eat up the wood of the tree branch. In the limestone deposits (below the

Coal-measures) carrying hæmatite, it is equally clear that these hæmatite deposits were placed *in situ* at the same time as the limestone selectors deposited the limestone. In the same way the chalk deposits were deposited by the chalk selectors, and flints by the silica selectors.

In the Silurian formation, the same rule applies, where they selected and deposited the so-called country or mother rocks, granite, slate, schist, quartzite, etc., they also selected and deposited the veins carrying silica, gold, silver, lead, etc., and built not only the beds or seams of quartz which lay conformably with the strata, and which often carry metals and metallic ores but also the veins or lodes which run in all directions through the mother rock.

The writer has made analyses of conformable beds or seams of quartz lying with the strata carrying gold and silver, and also of beds running at right angles through the mother rock, and in all respects they are the same—carrying arsenic, sulphur, iron, a trace of copper, antimony, and a little gold and silver, alumina, lime, magnesia, soda and potash, and larger proportions of silica, indicating pretty clearly that both cases of veins or deposits are of the same age. The writer is perfectly aware that his theory will be treated at first as absurd, but he has seen ample evidence to prove its truth. He has seen places where veins (or, as they are usually called, fissure-veins) were so close together that the rock could not have stood alone when "disrupted," but the whole would have fallen in a confused mass. How often have we seen veins running through and under, cutting each other, and how often do they lie at such angles that the roof of the so-called fissure-vein could not have remained hanging until the deposit was formed which filled it up.

The reader must not for a moment suppose that the writer does not believe that there are no true fissure-veins, veins which have been filled up after the rents or gaps were made, but they are few in number compared with the conformable quartz lodes, or those lodes or veins built up at the same time as the mother rock, and running in all directions through it. The well-known "horses" in veins never show any signs of having fallen into the so-called fissure, but they almost invariably begin as thin points and widen out, and are invariably of the same rock as the mother rock or elvan as it is called. If a "horse" is a portion of the mother rock fallen into the fissure, how could it keep its position till the vein matter was formed around it? The writer does not of course consider the case of slips of hitches where the adjoining strata is drawn into the veize or hitch; these of course must be considered fissure-veins.

The writer further believes that in many places the granites, slates,

schists, quartzites, and veins in them have been all formed at one and the same time under the same waters, and deposited at the angles the strata now possess, which generally varies from 65 to 75 degs. The writer is aware that the generally accepted idea is that these rocks have all been deposited practically level and afterwards tilted up at varying angles. Such has occurred in some cases, but in all the cases examined by the writer in the earlier formations, he is clearly of opinion that such rocks have been deposited at about their present angle. The writer has seen schist in granite, and granite in schist. He is aware that there are geologists who consider granite to be an igneous rock, but he has seen no evidence of this anywhere.

Broadly speaking, the writer's theory is, that nearly all the rocks (except igneous, and those brought up by thermal springs) are of microbe or selector origin; but how far microbe organism or selectors have had to do with the formation of rocks and veins from thermal springs, he is not prepared at present to say.

In the destruction of rocks, the writer is of opinion that microbes play a great part. Hitherto oxidation, heat, water, frost, and ice have been considered to be the great factors in tearing rocks asunder and reducing them to dust. No doubt these agents play their part, but they are not the sole agents. The writer has carried on experiments for many years in order to find out the causes of decay in stone and brick buildings, and in nearly all cases, this has been found to result from microbe life (the writer uses the word microbe in its broadest sense), and he has prevented further decay by simply treating the stone, brick, etc., with materials which prevent the microbes from living. These microbes or minute organisms carry on their work whenever they get water, moisture, or air, and suitable food. Whinstone is even eaten by them. The writer for many years could never understand why "till-clay," which must have been deposited in a plastic condition, or more likely as a mixture of mud, water, and stones, was hard and dry although below water, but he is now of opinion that this effect results from the action of microbes. The clay and stone were deposited in water containing these microbes, which set to work, using up the water, eating the stone and giving off carbonic acid gas and vapour and so dried the clay, expanding the material and preventing any water from entering. When this process is carried on at the bottom of a whinstone cliff, the writer has found what had been originally pieces of whinstone about 1 foot in thickness reduced to fine clay, and only a round bit of whinstone remaining in the middle an inch or so in diameter. In this case the circumstances admitted of air and water getting to the microbes.

How far do these microbes cause the roofs and sides of mines to give way? It is usually said, if air be excluded from the roof of a mine which gives way, you will have no further trouble. This may be right, but is it the air *per se* which destroys the roof? Do these micro-organisms destroy rocks below water, and render them soluble in water? If so, we have an explanation of how lochs are deepened and made larger.

Such are the writer's ideas on the formation of the rocks and their destruction. Broadly, his theory is, that by microbes the rocks are and are not.

Mr. H. Richardson Hewitt (Derby) wrote that the hypothesis thrown out by Mr. Aitken is a somewhat remarkable one, and is contrary to the opinions of geologists, although they say that microscopic organisms have played an important part in the construction of certain aqueous rocks. The idea that the whole of the aqueous range has been formed by marine exuviæ is certainly a novel one, and more facts, and not a few experiments, will be required before it can be accepted. If this hypothesis be the correct one all formations would be nearly devoid of fossils, as the only fossils left to us would be those which had escaped the devouring appetite of the microscopic organisms. Mr. Aitken states that "all through the coal formation there is an almost entire want of any evidence of the active wash of water," from which conclusion he (Mr. Hewitt) must dissent, as some or indeed many of the sandstones found near coal-seams have distinct wave-marks upon their surfaces. The writer knows many cases where this is so, but the most distinct of all he has seen are found in the roof of the Hollylane coal-seam in North Staffordshire, where the same feature is observed over the entire district. The Scottish coal-field must be a most peculiar one if the coal-seams run into cannel, ironstone, and common coal within an area of less than ½ square mile. In most coal-fields the seams do not vary in thickness or quality to any large extent in so small an area, unless the alterations are caused by a large number of faults, throwing the seams opposite to each other. Again the coal of to-day is composed chemically of carbon, hydrogen, and oxygen, the same elements—although slightly differing in proportion—which enter into the composition of plants, and as it shows evidence of vegetable structure it must therefore be of organic origin. Chalk is generally supposed to be a mass of foraminifera (lime-secreting organisms) and other microscopic forms, and he believed these animals may be seen in their entirety in a piece of rough chalk, and when placed under the microscope they appear as well preserved fossils. Chalk is said to contain

80 per cent. of these minute organisms, and the calcareous ooze of the North Atlantic ocean is similarly composed, so that it seems impossible for the whole of the Chalk formation to be the exuviæ of microscopic organisms.

Mr. George Lewis (Derby), referring to the previous day's excursions, said he only went over one portion of the ground. He must say that they had been very hospitably received. They showed them the scientific principles of the working. Yesterday they were told at the various works what was useful from a mechanical point of view or otherwise. The screening and washing processes were peculiarly interesting to him, and he had no doubt would be so to a great many other members. He had very great pleasure in proposing a very sincere vote of thanks to all those gentlemen who so kindly assisted them in every possible way in their journeys of the previous day.

The vote of thanks was cordially adopted.

Votes of thanks were also accorded to the local committee of the Mining Institute of Scotland who had made the arrangements for the reception of the members of the Institution, the President and the members of the Philosophical Society of Glasgow, and the Institution of Engineers and Shipbuilders in Scotland for the use of their rooms, and the President for his services that day.

The meeting then terminated.

The following notes record some of the features of interest seen by visitors to works, etc., which were, by kind permission of the owners, open for inspection during the course of the Scottish Meeting, on September 5th, 6th, and 7th, 1893:—

GLASGOW SUBWAY.

The subway in West Scotland Street is being constructed on the cut-and-cover system, and when finished will form two circular tunnels 2 feet 6 inches apart. The subsoil consists of sand saturated with water below a depth of 12 feet from the surface of the street. The bottom of the invert is about 22 feet down, which gives about 10 feet of wet sand to be gone through. Sheet-piling, 4 inches thick, has been driven along the sides of the street, and a double concrete arch thrown across on the sand, excavated to the shape of the arch. A layer of asphalte was then spread over the concrete and the street restored.

The wet sand was previously found to be too fine to drain in any reasonable time, and the concrete arch is presently being underpinned under about 2 lbs. of air pressure. This completely dries the sand and enables the work to be safely done.

From St. Enoch Square, four iron tunnels are presently being driven, two northwards up Buchanan Street, and two southwards towards the river Clyde. The material is running sand, and the tunnels are being driven under air pressure of from 6 to 15 lbs. on the square inch. The method of procedure consists in excavating a length of about 9 feet, polling longitudinally with 5 inch timbers as the excavation proceeds. A shield is used to keep the tunnel in shape, and this is pumped forward 18 inches at a time by means of eight rams (pressure about 1,700 lbs. to the square inch). A ring of iron is then built in and bolted to the last ring finished, the ring consisting of nine segments (weighing about 3 cwts. each) and a key-piece. This is carried forward till the length is finished, and as the iron is put in ring by ring, liquid Arden lime is forced through holes in the segments (left for that purpose) at a pressure of about 40 lbs. on the square inch. This completely fills up all crevices behind the iron ring and prevents any unequal pressure from coming on it.

GLASGOW CENTRAL RAILWAY.

The Glasgow Central Railway is being constructed by the Caledonian Railway Company under the city, and when completed will form a direct connexion between the existing lines from the north and south, as well as provide access by rail to the most important centres along its route, including the Queen's Dock at Stobcross.

With the exception of a portion at the west end towards Maryhill, the railway, which is about 6 miles in length, is altogether underground, and is being constructed for double lines of rails below the main thoroughfares, with stations at short intervals.

It commences by a junction with the existing line near Rutherglen, and, entering into a tunnel, runs practically east to west for the greater part of its length, traversing Dalmarnock Road, Canning Street, Monteith Row, London Street, Trongate, Argyle Street, Stobcross Street, on through Kelvingrove Park to Great Western Road, where it emerges to the open immediately west of the Botanic Gardens, and forms a junction with the Lanarkshire and Dumbartonshire Railway at Maryhill.

The method of construction is partly by tunnelling and partly by cut-and-cover; and, where the levels admit, the form of the covered way is

an arch, built of brick in cement; but where the available depth from the surface is insufficient for the arch, the roof is formed of steel girders and jack-arching. This latter form of covering is necessary at several places, particularly in Canning Street, Trongate, and Argyle Street, and a notable feature of this work is the construction under the busiest thoroughfares of the city, and the absolute necessity of placing the girders, building the jack-arching, and restoring the street during the cessation of traffic between Saturday night and Monday morning.

In Great Western Road the railway is being constructed by tunnelling proper on the English bar system under the main thoroughfares, through strata of boulder-clay and rock, with, at several places, an old coal waste intercepted at about formation-level of the railway. The coal-seam here has been about 2½ to 3 feet thick; but, being worked out it has been found necessary to underpin the rock above, and carry the foundation of the tunnel abutments down through the waste.

After leaving Great Western Road, the line runs due south under Kelvingrove Park, and, with many points of interest intervening, passes under Dumbarton Road and St. Vincent Crescent. Under the buildings in this vicinity, the tunnel is being formed on the core system by a somewhat novel method of construction, consisting of a series of concrete ribs built in cross tunnels at the soffit of the arch from a longitudinal tunnel at the crown. The method has been entirely successful, and the houses have been occupied during the whole of the operations, notwithstanding the fact that the crown of the arch is within a few inches of some of the basement floors.

After passing under the Stobcross Railway Depôt and alongside the Queen's Dock, the route is along Stobcross Street to Argyle Street.

From the Botanic Gardens to the west end of Argyle Street, the covered way is of the arched form, but in Argyle Street the headroom only admits of the steel girder roof already described.

In Argyle Street and Trongate, the covered way is to a large extent completed, and operations are now commencing for the construction of the Low-level Central Station, in connexion with which there are many interesting features, such as the means adopted for lowering of the water in the subsoil and extensive underpinning of the adjoining buildings. Eastward of the Central Station, the works are also of a varied and interesting nature; and, apart from the difficult construction of the railway proper, are characterized by extensive alterations of the water and gas pipes, as well as the existing sewers, and the substitution of what may be described as an entirely new sewerage system for the eastern district of the city.

CLYDE IRONWORKS OF MESSRS. JAMES DUNLOP & CO., LIMITED.

There are four blast-furnaces, two of them 60 feet, and two 74 feet high.

The blast is supplied by a large engine with two steam-cylinders 50 inches in diameter and 9 feet stroke, working two air-cylinders of 100 inches in diameter. This engine, foundation, and house was removed from the Oakley ironworks in Fifeshire, on the dispersion of the ironworks plant there, and erected complete on its present site. There is also an auxiliary blast-engine, one of the two smaller engines originally used for supplying blast. The air is heated by Whitwell brick stoves, and is blown into the furnaces at a temperature of about 1,300 degs. Fahr. The hot blast was first discovered and applied by Mr. James Beaumont Neilson at these works, but the iron-pipe heaters of his day have long since given way to brick stoves.

The company have recently erected a plant for dealing with the gases produced at the blast-furnaces, and extracting the usual bye-products. Four exhauster engines draw the waste gases through the plant, which consists of condensers for cooling down the gases, washers for purifying them, and apparatus for distilling the tar, and ammoniacal liquor produced.

The workshops comprise smiths', joiners', and engineering shops, and a large foundry, for the repair of the machinery at the works and collieries.

Electric signalling apparatus is used between the furnaces to prevent two of them charging at the same time, and between the furnaces and the ammonia works with the view of regulating the times of each going-on, and going-off blast.

The electric lighting installation consists of 13 arc lamps of 2,000 candle-power, and 150 incandescent lamps of 16 to 32 candle-power, worked by two engines and two dynamos, each of which can work either the incandescent or arc systems.

HALLSIDE STEELWORKS OF THE STEEL COMPANY OF SCOTLAND, LIMITED.

This company is the largest and oldest established makers of Siemens steel in the country, operations having been begun at the Hallside works in 1872. When in full working order the company can produce about 4,000 tons of finished steel weekly.

In the melting department the process of steel-making was shown, together with the method of gas-making.

In the mill and forge departments the steel is rolled into sectional

bars for ship or bridge-building, or forged into axles, cranks, or other forms for general engineering purposes.

In the foundry department, stern-frames, rudder-posts, and general castings of all kinds are moulded and cast.

The laboratory and testing departments are devoted to the purposes of proving and testing the raw materials and the steel when manufactured into finished products.

BARDYKES COLLIERY.

This colliery, belonging to Messrs. Merry & Cuninghame, Limited, has two oblong shafts, each 22 feet long by 7 feet wide. The No. 1 pit is sunk to the splint coal-seam at a depth of 1,320 feet. The seams worked are the ell coal, 3 feet 9 inches thick, at a depth of 1,140 feet, and the main coal, 3 feet 6 inches thick, at a depth of 1,224 feet. Both seams are worked on the longwall system. This pit is used as a downcast and pumping-shaft.

The pumping-engine is of Cornish type, with a cylinder 84 inches in diameter and 8 feet stroke. The pumps have a stroke of 9 feet, and consist of 22 inches, 20 inches, 18 inches, and 13 inches rams, with a lift of 300 feet each, and one 8 inches bucket with a lift of 120 feet.

The winding-engine has two cylinders each 28 inches in diameter and 5 feet stroke, and draws four hutches, each containing 11 cwts. of coal at a time.

The No. 2 and upcast pit is also sunk to the splint coal seam, the seams worked being the upper or Glasgow coal, 2 feet 9 inches thick, at a depth of 1,080 feet, and the ell coal as in No. 1 pit.

The mine is ventilated by a Guibal fan, 30 feet in diameter and 10 feet wide; and a Waddle fan, 25 feet in diameter, is held in reserve.

The winding-engine has two cylinders each 24 inches in diameter, and draws two hutches at a time.

The coal worked from both pits is brought to a central screening-station, and is deposited by means of revolving tipplers on shaking-screens; thence to Lührig picking-bands, where the lumps are prepared for market. The small coal or dross is elevated into a large sizing-drum, and divided into treble, double, single, and gum coals. These products are then washed in separate jigging-boxes, and dropped into hoppers ready for trucking. The plant is capable of treating 1,500 tons and of washing 600 tons of dross per day of 10 hours. The present output is 800 to 900 tons per day of 9 hours.

EARNOCK COLLIERY, NEAR HAMILTON.

Earnock colliery, on the estate of Mr. John Watson, of Earnock, and about 1,000 acres in extent, is situated about a mile west of Hamilton. The lessees are Messrs. John Watson, Limited; and Mr. Thomas Moodie is the colliery manager.

There are three shafts sunk near to each other. The thickness and depth of the four principal seams are as follows:—

	Ft.	Ins.		
Ell coal	6	9	thick at	720 feet.
Pyotshaw coal	4	3	„	774 „
Main coal	4	2	„	786 „
Splint and virgin coals, in one seam	7	2	„	854 „

Nos. 1 and 2 pits have been in operation for about fifteen years, and No. 3 pit has been recently sunk. The mode of working is chiefly stoop-and-room, some portions of the pyotshaw and main seams being worked by longwall.

The pithead-framing and other surface erections are all of wrought iron or steel, the headgear of Nos. 1 and 2 pits being of wrought iron and 50 feet in height, while that of No. 3 pit is of rolled Bessemer steel girders and 65 feet in height.

The colliery is drained by a Hathorne-Davey compound condensing engine, the high-pressure cylinder being 22 inches in diameter, and the low-pressure cylinder being 36 inches in diameter. This engine is situated in the main coal seam at a depth of 786 feet near No. 1 shaft.

Ventilation is effected by means of a Guibal fan, 40 feet in diameter by 12 feet wide, producing 200,000 cubic feet of air per minute with 2·5 inches water-gauge, at a speed of 46 revolutions per minute.

The steam power is produced by seven Lancashire boilers, each 30 feet long by 7½ feet in diameter, at No. 1 shaft; and three Lancashire boilers at No. 3 shaft, each 30 feet long by 7 feet 9 inches in diameter; the latter being fired by Bennis mechanical stokers.

The output of Nos. 1 and 2 pits, which produce 1,200 tons a day, is raised by No. 1 pit, the No. 2 shaft being reserved for the raising and lowering of workmen and materials. The winding-engine at No. 1 shaft has two horizontal cylinders, each 28 inches in diameter by 60 inches stroke, fitted with drums 12½ feet in diameter. The conductors in the shaft, one on each side of the cage, are flat-bottomed steel rails weighing 35 lbs. to the yard. The cages are two-decked, holding four tubs, and the winding-ropes are of plough steel, 1½ inches in diameter.

The winding-engine at No. 2 shaft has two horizontal cylinders, each 18 inches in diameter by 36 inches stroke, fitted with a drum 9 feet in diameter.

The No. 3 pit winding-engine has two horizontal cylinders, each 30 inches in diameter by 60 inches stroke, fitted with drums 16 feet in diameter. The conductors are similar to those used in No. 1 shaft, and the cages carry two tubs each, one above the other.

The principal haulage is by the main-and-tail-rope system, the gradients being sometimes with and sometimes against the load, and varying from level to 1 in 12 either way. The length of the roads traversed by this system are 2,480 yards in the ell coal seam, and 1,240 yards in the main coal seam; 30 to 40 tubs are run in each train in the ell coal haulage, and 14 to 18 in that of the main coal seam. The hauling-engines are situated near No. 1 shaft in the ell coal-seam.

There is a system of electric haulage, supplemental to the main-and-tail-rope haulage, doing the work of a number of horses that formerly hauled from the coal-faces to the termini of that haulage.

Two Westinghouse engines situated on the surface, running at 360 revolutions per minute, supply 60 brake horse-power direct to a line of shafting, from which three dynamos are driven by belts. One of the dynamos, which is that used for the haulage, generates power for two motors underground, and runs at a speed of 610 revolutions per minute. This dynamo is compound-wound and capable of producing a current of 100 ampères at 500 volts, equal to 67 horse-power. The other two dynamos are used in connexion with the lighting of two mansion-houses on the estate. A copper cable connects the dynamo with the motors underground, one of which gives off to an endless-rope haulage, 35 horse-power; and the other to another endless-rope haulage, 12 horse-power. Hurd clip-pulleys are used at the motors.

The surface-works and shaft-bottoms have been lighted by electricity since 1882. Three dynamos are driven by an engine with a cylinder 10 inches in diameter and 20 inches stroke, the speed of the dynamos and engine being in the ratio of 15 to 1. The dynamos are shunt-wound and supply electricity to sixty 32 candle-power lamps for the pitheads and a similar number used underground.

There is a system of oscillating screens of perforated steel plates, delivering on travelling tables 30 feet long by 4 feet wide, where the round coal is picked and passed on to the trucks. Conveyers are attached, by which the small coal is taken to a Robinson washer, the nut coal being intercepted by a vibrating screen on the way. After being washed the small coal is passed over several sizes of vibrating screens, and falls into the trucks as bean, pea, and pearl coal, while the duff coal is recovered by another process, and the water cleared for use over again.

FAIRHILL COLLIERY, NEAR HAMILTON.

This colliery, fully 60 acres in area, held by Mr. Archibald Russell, of Auchinraith, is fitted up for an output of 1,000 tons per day. There are two oblong winding-shafts, each 22 feet long by 6½ feet wide, sunk to a depth of 880 feet. Both pits are lined with 5 inches pitch-pine boarding at the surface and 3 inches white-pine at the bottom.

The winding engine at the No. 1 or downcast pit has two horizontal cylinders, each 24 inches in diameter and 5 feet stroke, fitted with winding-drums 14 feet in diameter. The steel winding-rope is 3½ inches in circumference. The cage weighs 18 cwts., and lifts two hutches, each weighing 4 cwts., and holding 10 cwts. of coal, the total working-load being 2 tons 6 cwts.

The horizontal winding-engine at the No. 2 or upcast pit has two cylinders, each 24 inches in diameter and 4½ feet stroke. The winding-drums are 12 feet in diameter, and the appliances are similar to those at the No. 1 pit.

The ventilation is produced by a quasi-Guibal fan, receiving air at both sides. The fan is 24 feet in diameter and 7 feet wide, and is driven by an engine with a cylinder 16 inches in diameter and 2½ feet stroke.

The horizontal pumping-engine has one cylinder 20 inches in diameter and 4 feet stroke. It is geared 3 to 1, and makes 9 strokes per minute. The top lift of the pumps has a 14 inches bucket and the bottom lift a 13 inches bucket, and the engine is lifting 420 feet from the bottom lift. A small Worthington pump is placed in the shaft at a depth of 84 feet.

There are eight boilers of the egg-ended type, each 30 feet long by 5½ feet in diameter, working at a steam pressure of 50 lbs. per square inch, fitted with patent dampers, and fed by a Hulne & Lund vertical donkey-pump, with a Worthington donkey-pump in reserve. The exhaust steam from the winding-engine is used to heat the feed-water.

The cleaning plant consists of a slow-motion jigger and picking tables for cleaning the round coal and making nuts.

Three seams are now being worked, the ell coal, 7 feet thick, at a depth of 740 feet; the main coal, 4 feet thick, at a depth of 816 feet; and the splint coal, 7 feet thick, at a depth of 880 feet. These seams are all worked on the stoop-and-room system.

Horses are used for the underground haulage.

NOTES ON THE MACARTHUR-FORREST PROCESS OF GOLD EXTRACTION (THE CASSEL GOLD EXTRACTING CO., LTD.).*

The gold-ore is ground to about the fineness of sea sand. If, instead of ore, tailings from the amalgamation process are being worked, these are generally not reground, but treated as delivered. The finely-divided material is mixed with a solution of a cyanide, say cyanide of potassium, containing on an average 0·4 per cent. of cyanogen as the cyanide of potassium or other alkali or alkaline earth. The ore and solution are stirred together for about six hours, more or less, this being the average time required to dissolve the gold; in practice the time required is determined by direct experiment.

When the gold is known to be dissolved, the pulp is discharged into an ordinary filtering-tank, where the filtration may, if necessary, be assisted by suction, and where the ore is washed by water or by the waste cyanide solution from a previous operation. The ore, after treatment with cyanide solution, is unchanged to the eye, as almost nothing but the imperceptible proportion of gold present has been removed.

The gold now being in solution, the next object is to get it precipitated, which is done by passing the liquid through a porous mass of zinc, like a sponge, forming a chemical filter which at once precipitates and collects the precious metal; indeed, so like an ordinary water-purifying device is this zinc filter, that many visitors form and hold tenaciously to the idea that the gold is in suspension in the cyanide solution, and that the zinc is used merely because of its durability.

When the gold is deposited, it is necessary to separate it from the excess of zinc present. The filiform structure of the zinc, and the exceedingly fine powder in which the gold is deposited, renders this an easy matter. The filiform mass of zinc with gold powder adhering is vigorously shaken in water, when the gold falls off, and the fibrous particles of the zinc may be collected in a sieve. The gold settles easily, is collected, and fused directly into bullion.

HAMILTON PALACE AND CADZOW FOREST.

Hamilton Palace and Mausoleum are situated quite close to the older part of the town of Hamilton, the street of which at one time extended past the south front of the palace, the old Tolbooth erected in the reign of Charles I. being attached to the stables, and now used as a store for the accoutrements of the Hamilton troop of Yeomanry. The park by which

* *Trans. Fed. Inst.*, vol. iv., page 372.

they are surrounded is finely wooded, and extends to about 1,000 acres lying along the left bank of the river Clyde. The older portion of the palace fronting the south was erected in 1705, but the greater part of it as it now exists was built by Alexander, tenth Duke of Hamilton, grandfather of the present duke, in 1822, and subsequent years, and occupies the site of a much older portion, dating from 1591. Both fronts are worthy of careful inspection, and especially the Corinthian portico of the north or new front, with its monolithic columns, 25 feet high. The interior is planned on a scale of equal magnificence.

The mausoleum was commenced by Duke Alexander, and completed after his death by Mr. David Bryce, R.S.A., Edinburgh. The chapel is octagonal, and is adorned with sculptures by Mr. A. Handyside Ritchie and lighted by a dome 120 feet high. The lions on the east side of the building and the carved masks over the entrance to the vaults are by the same artist. The chapel doors are of bronze, copied from the celebrated gates of Ghiberti in the Baptistry of Florence, and are the work of Sir John Steel, R.S.A. The six panels illustrate scripture subjects. Within the chapel and opposite the door is an Egyptian sarcophagus containing the embalmed body of Duke Alexander.

In Cadzow, the chief objects of interest are the Old Oaks, the White Cattle, and the ruined castle of Cadzow. The Old Oaks are of unknown age, believed to be the remains of the great Caledonian Forest, and in an advanced state of decay. Some of them are of great girth. The fields in which most of those still remaining are to be found are pastured by the herd of white cattle, generally regarded as (along with the herd at Chillingham Park) the last surviving descendants of the native wild cattle. They are entirely white except their hoofs, ears, and muzzles, which are black. The herd now numbers about sixty.

Cadzow Castle stands on the left bank of the river Avon, and crowns a precipitous rocky bank about 200 feet high. Nothing is known as to its erection. It was a royal residence in the reigns of Alexander II. and Alexander III., passed in the time of Robert Bruce into the possession of the Hamiltons, and is now a complete ruin.

The pavilion or summer palace of Chatelherault stands on the opposite bank of the river, where it terminates the fine avenue of trees, over two miles in length, stretching to the palace and onwards to Bothwellhaugh.

The scenery of the glen of the Avon is well worthy of notice, and very fine views can be obtained from a variety of points.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE ROYAL VICTORIA HOTEL, SHEFFIELD,

AUGUST 26TH, 1893.

MR. W. E. GARFORTH, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected Members of the Institute, having been previously nominated:—

Mr. WILLIAM BEST, Engineer, Morley, near Leeds.
Mr. PERCY C. GREAVES, Mining Engineer, Wakefield.
Mr. ROBERT WORMALD, Mining Student, Barrow Collieries, Barnsley.

The PRESIDENT read his inaugural address as follows:—

PRESIDENTIAL ADDRESS.

By Mr. W. E. GARFORTH.

My first duty is to express my thanks for the compliment you have paid me by re-electing me your President for the ensuing year. I trust, with a continuance of your help, that, together, we may increase the usefulness of this Institute. Under the circumstances of my re-election I have presumed you will not expect the usual presidential address, but, in the absence of other papers which the Council expect will be shortly submitted by certain members, I beg to offer the following remarks:—

At a previous meeting I drew attention to the fact that mining engineers and colliery managers had, by their skill and ingenuity, been able to produce (under greater difficulties as regards increased depth from the surface, and with the coal-face a longer distance from the shaft) an output of coal equal to the demand, and indeed as regards profits probably in excess of it. A large number of inventions in electrical appliances and mechanical arrangements had been rendered applicable to mining operations. And that an ingenious arrangement for detecting small percentages of fire-damp had been invented within the past year.

But whilst we had reason to congratulate ourselves on these improvements, we had again to deplore serious loss of life from colliery explosions. The most recent disaster had occurred within the last few weeks at a West Yorkshire colliery, resulting in the loss of 139 lives. I therefore ventured to suggest that the various societies forming the Federated Institution of Mining Engineers should make an attempt to collect information from those members who had special experience in recovering a mine after an explosion, with the view of judging whether a comparison of their individual experiences would show them to be sufficiently alike on certain points, and whether one would be able to formulate a code of rules for the guidance of those who might, in the future, be unexpectedly called upon to render assistance after a colliery explosion.

We all know that the subject of colliery explosions has occupied the attention of the most scientific and experienced men of this and other countries for the last century. The result has been to place before the mining world a full and detailed account of the cause of many of these

accidents. Conclusions have been drawn from such accounts, and remedies suggested which have been the means of preventing many explosions which otherwise might have taken place.

At the same time, I have never seen a detailed description of the means which have been adopted for recovering a pit after an explosion, especially as regards:—

(*a*) How the survivors were rescued.

(*b*) The advisability of using certain portions of the return airway.

(*c*) The precautions taken to prevent a second explosion.

(*d*) The systematic use of the anemometer and regular reports of the air-currents under the altered conditions consequent on the doors, air-crossings, etc., being destroyed. The use of small ventilating fans and engines for driving and arrangement of wooden foundations for same, in order to obtain as quickly as possible a sufficient quantity of air to assist the explorers.

(*e*) The means taken to extinguish standing fires at long distances in-bye.

(*f*) The organization of search parties with a view of not having too many explorers in the pit at one time.

(*g*) The best means of sending along the roads and up the shaft the bodies of those killed, especially in cases where the same have been lying in the pit some days or weeks after the explosion.

(*h*) Arranging for the removal of the *débris*, for instance where the road has been broken down to a great height, it may prove advantageous to raise it generally throughout by allowing the heavy falls to fill up those places where no falls have taken place, thereby saving stone and dirt being sent to the surface.

(*i*) The use of air-pipes over falls of roof instead of brattice-cloth, which latter cannot be made tight over *débris* or a high fall, even with the most careful stitching.

(*j*) Re-opening of the pit for regular work as expeditiously as possible.

(*k*) Other matters of detail as to restoratives, etc.

I can understand that if colliery explosions had been of more frequent occurrence some better arrangements than those now ordinarily made would many years ago have been suggested. Happening so rarely, and each colliery where an accident happens being, as the newspapers say, "con-

sidered the safest pit in the district," the manager prefers to turn his attention to the prevention of ordinary accidents rather than trouble himself with matters which are dependent on an explosion which may never occur. It is also recognized that no two pits are exactly alike, owing to the position of faults, the shape of the coal-field, etc.

The foregoing are probably some of the reasons connected with the present unsatisfactory state of affairs, which many of you are aware may be briefly described as follows:—

On hearing of an explosion at a neighbouring pit, there is a general rush to render assistance. Arriving at the colliery, it is found that the manager and other officials are in the mine. No other person connected with the colliery likes to say what is being done except that the return-airways are being carefully watched and noted. No plan or section of the workings is visible. Considering that some of the would-be explorers are connected with neighbouring collieries it would not be reasonable to expect that the working-plan, showing the boundary of the coal-field and other private information, should be open for general inspection. Consequently, nothing can be done until the manager returns to the surface, except conjecture as to the loss of life and the possibility of existing fires.

When the manager appears he is probably exhausted by his exertions, distressed at the loss of life, and perplexed as to the cause of the explosion. With the help of a board and piece of chalk he, however, endeavours to show the main roads in the pit, etc. With such slight information the mining engineers and colliery officials, who have volunteered to help, are often asked to take the responsibility of closing the mine, leaving the bodies unrecovered or otherwise incurring serious responsibilities. If their advice does not prove entirely satisfactory, they are subjected to a large amount of public criticism and sometimes severe censure. In addition there may be large claims under the Employers' Liability Act.

With the view of seeing whether any improvement can be made on the present state of affairs, I have, at the request of several members of this Institute, promised to give at a future meeting the result of my own experience. In the meantime I beg to suggest, for the consideration of members of the Federated Institution of Mining Engineers:—

1.—That a skeleton plan of the underground workings should be prepared giving the direction of the main intake and return-airways, the crossgates and working-places and the various splits of air, but without showing the bearing of the same with respect to the surface; and a section of the pits, if more than one mine is worked from the same pair of shafts.

The plan and section should be kept in a convenient place in the office ready for immediate reference and known, not only to the manager but, in case of his death, to some one connected with the office.

2.—A chart or system of recording the various ventilating currents should be adopted.

3.—If the cages in both pits are damaged, an arrangement of pulleys or appliances for getting into the pits should be provided.

4.—Other suggestions might be made which would exceed the limits of this address, but which should be carried out or decided upon during the ordinary working of the colliery and not left to the time of excitement which usually follows an explosion.

I can fancy that those gentlemen who have never passed through the sad experience following an explosion, and who have taken every possible precaution to avoid one, may say that my propositions are unnecessary, and that there is at the present time too much red-tapeism and too many restrictions in carrying out the several Acts of Parliament relating to colliery management. My answer is that it is generally the unexpected which happens.

I may also explain that my propositions cannot possibly do any harm, financially or otherwise; they may, on the contrary, be the means of increasing the standard of efficiency. If members in coal-mining districts which have been subject to colliery explosions, would give the benefit of their experience to members in other districts, hitherto free from such disasters, but in which difficulties may arise consequent on deeper mines being worked, it would, I think, add another advantage to those already gained by the federation of mining institutes.

In former times explosions were generally caused by accumulations of fire-damp, and the roadways of the pit were often formed in solid coal. In recent years some colliery explosions have been rendered more destructive by coal-dust, and owing to the roadways being made through goaf with the roof resting for long distances on timber, the falls have been more extensive and difficult to penetrate after the timber has been displaced by the blast than in roads with coal sides.

As coal is worked at greater depths, pillars of coal will not be left, owing to the superincumbent weight, consequently a larger area of coal will be worked from the same pair of shafts, and for obvious reasons the collieries will be of greater magnitude, and therefore more difficult to recover after an explosion.

Statistics show that explosions previous to 1860 resulted in 2·98 lives being lost per explosion; and since that time the loss has been at the rate of 6·25 lives per accident.

In conclusion, I think an attempt should be made to establish rules in the way suggested. If we do not succeed the discussion may at least have benefited some members. For instance, if they meet at the scene of an explosion, which is not unlikely, then the interchange of ideas which has taken place at a meeting of the Institute may be the means of saving time, when a few minutes are of vital importance.

If, from a large number of facts and the practical experiences which I hope we shall succeed in obtaining from the various members in the districts covered by the Federated Institution of Mining Engineers, we can frame a set of rules (to be bound in the form of a small pocket-book ready for instant use), then I believe we shall have carried out a scientific work and done something to help future generations in the difficulties they will have to encounter.

Mr. A. M. CHAMBERS thought it would be the feeling of the meeting that they should pass a vote of thanks to the President for his address. The suggestions that he made were worthy of consideration, and he hoped they would have the consideration of every member of the Institute. He had great pleasure in proposing a hearty vote of thanks to the President.

Mr. G. B. WALKER seconded the motion. None of them knew when they might have the terrible task of assisting at some such accident as had happened from time to time in the district. He had himself felt very strongly the force of what the President had said, that these things were regarded as unlooked for and unexpected, and, when the time came, preparations were not made for them, and much valuable time and many valuable lives might be lost in consequence. The President's suggestion was worthy the attention of all of the Federated Institutes. He trusted the address might have the result the President hoped for—the formulation of rules which would prove of value in the future.

The motion was carried unanimously.

The PRESIDENT, in reply, said he hoped before twelve months had elapsed that they would, by written communications or by discussion, be able to formulate and agree upon some rules.

Mr. L. DOBINSON read the following paper on "The Victoria Friction-clutch":—

THE VICTORIA FRICTION-CLUTCH.

BY L. DOBINSON.

In response to the President's request, the author has pleasure in describing the friction-clutch now in use at Parkhill colliery. The author would like other members of the Institute who have friction-clutches in use, to describe them with drawings, and thus the *Transactions* would truly become a book of reference on this very important part of mining machinery.

The friction-clutch to which the author refers is now known by the name of the Victoria friction-clutch. The wheel *a* (Figs. 1, 2, and 3, Plate VIII.) is of the ordinary type, having a tapered trod, with an inclination of about 1 in 5; the surface on which the rope works is covered with removable steel segments *b*, $\frac{1}{2}$ inch thick, to save the wheel-trod from wear; the steel segments last an indefinite time; some have been about four years at work, and during that time subject to the wear of a plough-steel $\frac{7}{8}$ inch rope, running constantly, either pumping or coal-hauling, with little or no signs yet of needing repairs. The rope leads on to the wheel at the side of the greater diameter, and off at the smaller diameter, thus fleeting easily, working smoothly, and doing the rope less harm, perhaps, than any other wheel for the same amount of frictional power secured.

In this class of wheel, the number of turns or laps of the rope on the wheel can be increased, until the necessary friction is secured; a method of obtaining additional friction which is difficult to affect with an ordinary C-pulley, owing to the fact that, if too much rope be put on, the leading rope crosses, becomes fast, and, if not, it always has a tendency to squeeze, and cause damage to the rope as it leaves the wheel, by climbing up the steep and inclined flanges, and forcing the coils very tightly down into the centre of the wheel. The C-wheel for light work, where few turns are required to secure friction to work the load, is as good as any, but where friction is demanded, and more turns of the rope round the wheel are required, then, in the author's opinion, the wheel with a tapered steel-lined trod is the best, having the whole width between the flanges avail-

able to receive rope without any further increase in the diameter of the wheel, than the inclination agreed upon (1 in 5). When the steel lining is worn out, or thereabouts, it can easily be renewed, and thereby retain the wheel as good as when new.

The frictional ring (Fig. 4) fits into a circular friction-pan *e*, formed on the wheel (Fig. 5), and is kept in its place by two semi-circular plates (*c*) studded to the wheel when in working position.

The driver (*d*), being a through or double driver, takes hold of the frictional ring at opposite sides of the shaft, and thereby carries it beautifully round, independently of the wheel when not in use.

The circular friction-pan is lined with steel or other suitable lining (*e*), in order to have a surface as hard as possible, so that the wear is reduced to a minimum, and saving the wheel from destruction. When the wheel is put into motion two wedges (*f*) on opposite sides of the main driving shaft, and at right angles to the drivers, are forced in, thereby distending the ring and pressing its surface against the surface of the pan and driving it round together as one body. To ensure the perfect working of the wedge it is made with a projection on each side, and the driving ring is recessed to the same extent to receive the wedge; hence there is no fear of its tilting, and the wedge is reliable in its action.

The parts of the ring, which receive the wedges are deepened to make the travel of the wedge as long as possible, thus preventing to a great extent the changing of wedges and bolts, simply requiring the lengthening of the bolt by screwing it out a turn or part of a turn to keep the wedge up to its work. As the frictional ring wears, the wedge of necessity must be forced further to distend the ring firmly against the smooth surface of the rigid pan. Both the openings of the rings and the wedges are inclined similarly, so that any advancement of the wedges has a telling effect on the distension of the ring, and being distended by two wedges it is soon in and out of gear, as may be desired by the operator. The wedges are actuated by a sleeve (*g*) on the driving shaft, an adjustable bolt connecting them; this bolt must be capable of elongation to meet the wear of the frictional ring. If the sleeve be up its distance, and the wedges have not inserted themselves sufficiently into the two openings of the ring, then the bolt (*h*) must be lengthened without removal and consequent loss of time. To obtain this, the bolt has a swivel (*i*), slot joint and screw with box. The lengthening or shortening is accomplished simply by screwing the bolt out or in as required, instead of as formerly by the removal of the bolt altogether.

When the wedge is forced home, that is to say, against the rigid pan,

and the bolt as far out the coupling box as it will allow, then the wedge must be changed for a wider one, and so on until the frictional-ring is worn out, or becomes so thin as to be unreliable, when a new frictional ring and smaller wedges are substituted.

The wear is so slight that the wedges last in regular work several months. The sleeve is moved backward and forward on the driving shaft by a pair of arms (k) keyed to a weigh-bar. This bar is turned to the right or left (in and out of gear) by the attendant as required. When the wedges are drawn back and the friction taken off, the frictional-ring is carried round by the drivers (fitting into a recess in the ring) without moving the wheel, when other wheels are kept going on the same driving shaft. There are four such wheels as the one described working on the main driving-shaft at Parkhills colliery, any one of which may go whilst the others are standing. If the attendant be careful only to put sufficient friction on to work the usual load, then immediately when more weight is applied, either by design or accident, the frictional ring surges and the wheel stands, hence the ropes and tubs are saved from damage, or any undue strain; for instance, should the tubs get off the road, or a fast clam, or any other accident by which a fast hold may be caused, the surging of the ring is a safeguard against damages of a costly nature and stoppages to coal-work. This if attended to is very beneficial, and the importance of it should be pressed upon the person in charge of the machinery. As in starting the ropes and load it takes considerably more friction to overcome the inertia and get the load into motion than it takes when the speed is secured to keep it going, the attendant should reduce the friction until he has just sufficient left to keep it nicely going, then if anything occurs on the roads the wheel stops, and the attendant knows there is something wrong before any serious damage is done either to ropes or to other rolling stock.

The friction-clutch can be seen on any working day, driving about 3,500 yards of rope, two three-throw pumps with 4 inches and 3 inches plungers respectively, and with vertical heads of 300 feet and 91 feet, also hauling coal. Full and empty tubs, ropes, and pumps, are equal to a force of 6 tons on the periphery of the frictional surface. The author considers this a reliable friction-clutch for heavy work, and is thoroughly satisfied with its working. The total weight of the mass in motion is about 40 tons. The above described frictional mechanism may be employed for driving purposes other than hauling wheels where it is required to intermittently or continuously transmit motion. The wheel and clutch being made in two halves facilitates the conveying, removing

from off the shaft, and fixing when renewals are required, without disturbing any other wheel on the same shaft; also being constructed in that manner it lessens the weight for the workmen to handle, and thereby increases the safety of the operation.

The PRESIDENT said he had great pleasure in proposing that the best thanks of the Institute be given to Mr. Dobinson for the trouble and time that he had given to the preparation of the paper.

Mr. GREAVES had great pleasure in seconding the vote. He had seen the friction-clutch and considered that it worked very well.

The motion was carried unanimously.

Mr. W. HOOLE CHAMBERS asked how long it took to throw the friction-clutch in and out of gear?

Mr. DOBINSON said it took three or four seconds.

The PRESIDENT asked what the gradient was, and whether the road was an undulating one?

Mr. DOBINSON said some parts of the road were undulating, but, beyond a certain point, the whole of the strata bent heavily down towards a 200 yards rise fault, and for a length of 500 yards the road dipped at the rate of 1 in 4·3. In another branch, worked by the same friction wheel, the gradient was 1 in 13 against the load.

The PRESIDENT said he had seen the friction-clutch at work. With the ordinary clutch it sometimes took three turns before they got the slightest movement, and at the fourth turn they got a sudden movement, but there was nothing of the kind in this clutch, the moment the wedges were taken out the apparatus began to act and worked smoothly.

Mr. DOBINSON said he thanked the members for their vote of thanks. He would be pleased to show the friction-clutch at work to any member who desired to see it.

On the motion of Mr. A. M. CHAMBERS, and seconded by Mr. G. B. WALKER, a vote of thanks was accorded to the President, who briefly replied, and closed the meeting.

"Friction-clutch."

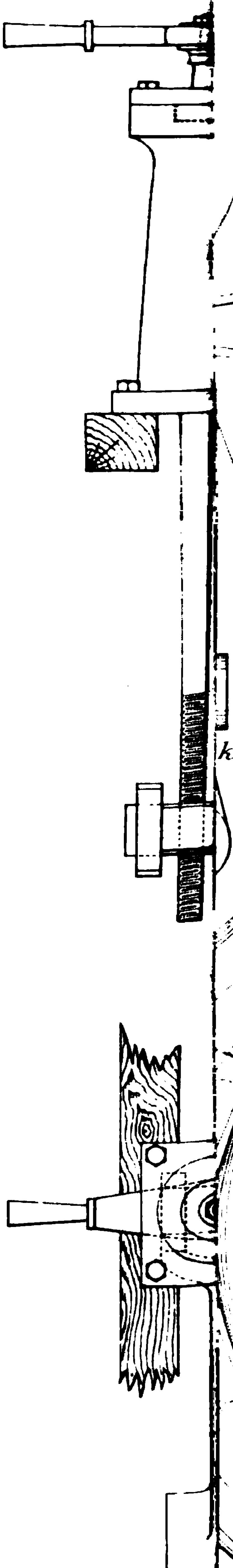
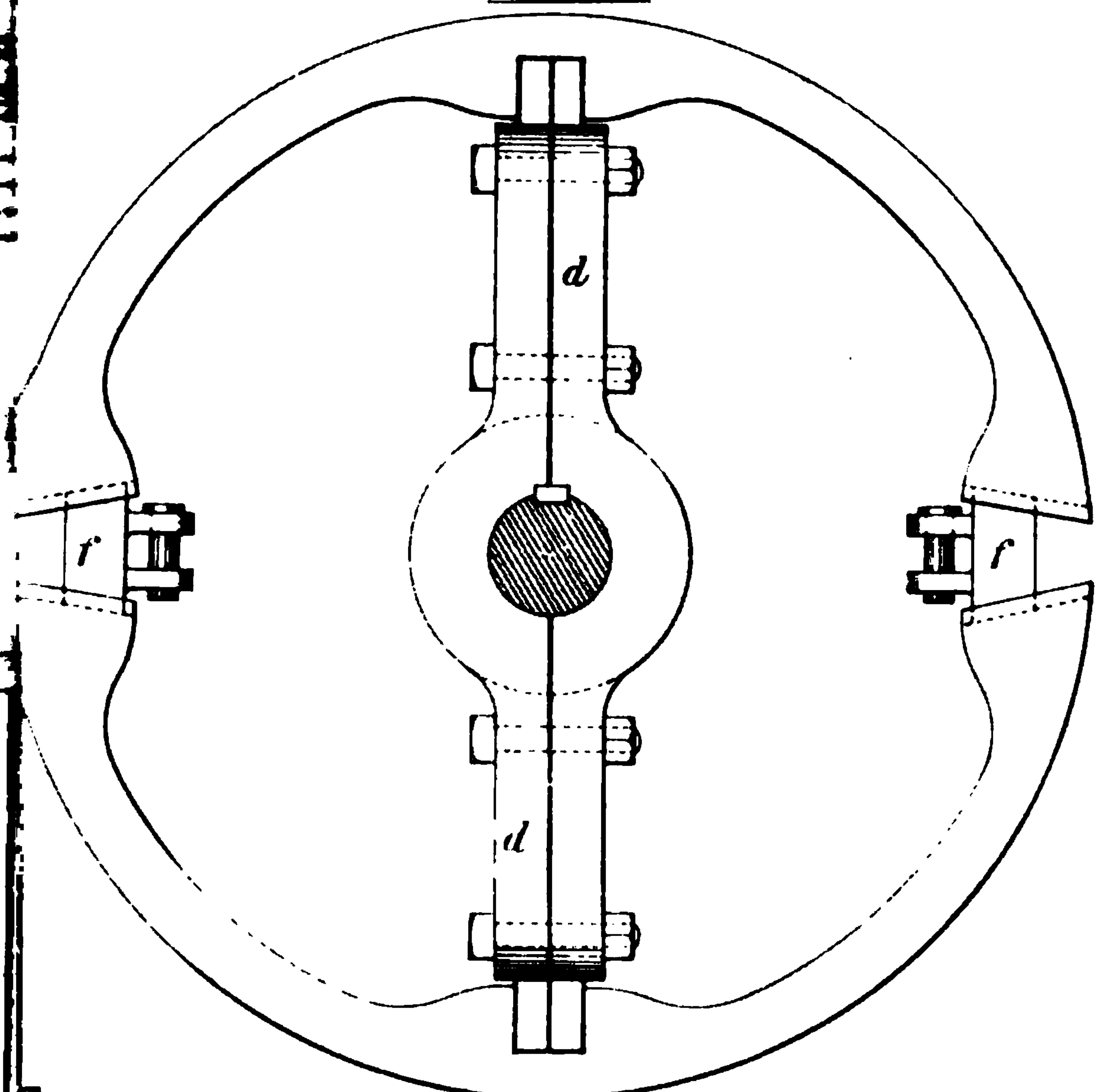
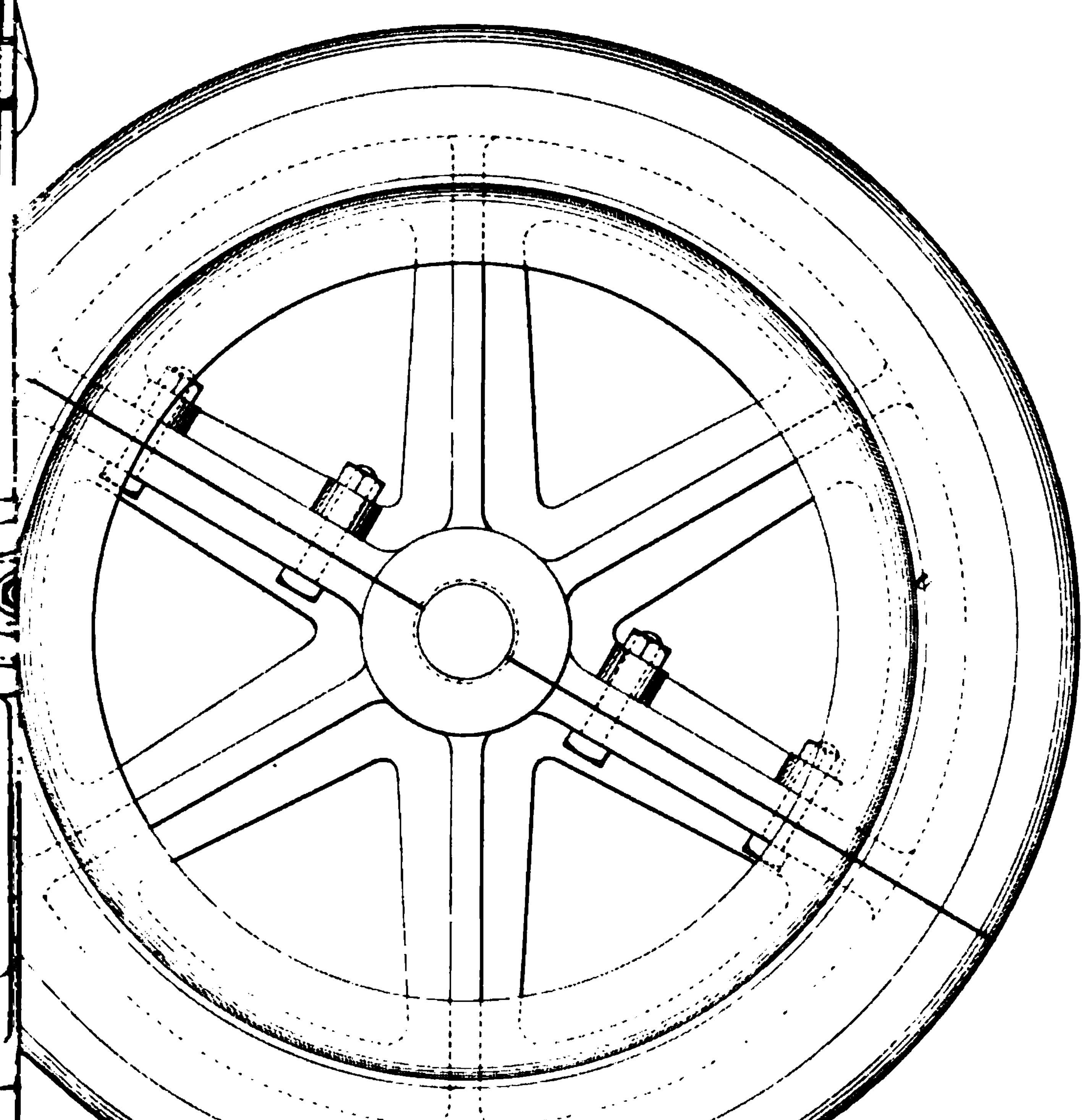


Fig. 4.



SPRINGS, DRIVER & WEDGES.

Fig. 5.



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COVER-PLATE,

SPRINGS, DRIVER, &c

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

ANNUAL GENERAL MEETING,
HELD IN THE MASON COLLEGE, BIRMINGHAM, OCTOBER 2ND, 1893.

MR. W. F. CLARK, RETIRING PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of the Council meetings were read and confirmed.

The following gentlemen were elected:—

MEMBER—
Mr. THOMAS WILLIAMS, Mining Engineer, Goldthorn Hill, Wolverhampton.

ASSOCIATE MEMBER—
Mr. THOMAS WILLIAMS, Manufacturer of Colliery Implements, Halesowen.

ELECTION OF OFFICERS FOR 1893-94.

The Scrutineers reported that the following gentlemen had been duly elected:—

PRESIDENT.—Mr. G. H. CLAUGHTON.
VICE-PRESIDENT.—Mr. H. C. PEAKE.

NEW MEMBERS OF COUNCIL.

Mr. J. T. WILLIAMSON.
Mr. R. SMALLMAN.
Mr. W. H. WHITEHOUSE.
Mr. D. ROGERS.

The SECRETARY read the annual report of the Council, together with the auditor's report, and accounts as follows:—

REPORT OF THE COUNCIL FOR 1892-3.

The period embraced by this, the twenty-sixth Report of the Council, has extended from January 1st, 1892, to July 31st, 1893, so as to fall in with the year of the Federated Institution of Mining Engineers, and get over several financial and other difficulties arising from the years of the two Institutes not running concurrently. It was fully explained in the last Report that, as this Institute federated in January, 1890, about the middle of the year of the Federated Institution of Mining Engineers, and was liable for a full year's contributions, it had always a half-year's

arrears standing to its debit. This has now been cleared off, out of the funds, and the next year will commence on August 1st, the date adopted by the Federated Institution of Mining Engineers.

During the period, nine General Meetings, ten Council Meetings, and five meetings of the Technical Education Committee have been held.

There are now 128 members on the list, or 9 more than last year; 24 new members have been elected, but 6 have died; 3 have resigned, and 6 have been struck off by Council in accordance with the rules.

Included in those unfortunately lost by death are Mr. Joseph Cooksey, who joined the Institute at its commencement on January 21st, 1867, and was President in 1871; and Mr. H. J. Marten, who joined in 1868. Both these gentlemen stood high in the profession, and were greatly esteemed for their good qualities. Two other original members, Mr. Benjamin Callear and Mr. John M. Fellows, who were much respected, are also in the obituary list.

The receipts have amounted to £261 18s. 6d., and the ordinary expenditure to £247 14s. 10d., leaving a balance of £14 3s. 8d., but this has been utilized, together with £35 3s. 10d. from the funds, to clear off the half-year's arrears, mentioned in the first paragraph of this Report, £37 2s. 6d, and to pay a special call of £12 5s. by the Federated Institution of Mining Engineers to meet the deficiency on the first three years; now, therefore, the balance in the bank is £274 15s. 7d., and there are other assets, such as arrears of subscriptions, furniture, and property at the rooms, etc.

The President, Mr. W. F. Clark, in his inaugural address, dealt very fully and very ably with the important Mines Drainage Scheme, showing the present position of South Staffordshire with regard to the mines drainage operations and its liability for the mines drainage loans.

The following papers have been read:—

"The Application of Electricity in Mining." By Messrs. Atkinson.

"Electric Haulage at the Cannock and Rugeley Collieries." By Mr. R. S. Williamson.

"Electric Haulage at the West Cannock Colliery." By Mr. W. Wardle.

"Practical Notes on the Geology of Wirral." By Mr. W. Fairley.

"Compressed Oxygen." Prof. R. H. Smith.

"Notes on an Earth Explosion or 'Bump' at Hamstead Colliery." By Mr. F. G. Meachem.

"Engineering Scraps in Australian Coal-mining." By Prof. W. E. Benton."

"Description of Mining Relics found at Heath End Colliery." By Mr. W. B. Scott.

"Description of the South Dyffryn and Abercanaid Collieries." By Mr. E. J. Bailey.

"The Spontaneous Combustion of Coal." By Mr. H. W. Hughes.

The last one, on "The Spontaneous Combustion of Coal," elicited a very good discussion.

A prize was awarded by the Federated Institution of Mining Engineers to Messrs. W. F. Clark and H. W. Hughes for their paper upon the South Staffordshire Coal-field read during the previous year.

The rules have been altered in accordance with the wish of the Federated Institution of Mining Engineers, so that now the membership consists of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students.

The Council are desirous of making the Institute as useful as possible; they feel that members should do all they can to influence the joining of Associates, who are under-managers, and those in subordinate positions in any of the branches of engineering or metallurgy, as well as Students, who are all admitted to the Institute at reduced fees and thus become part of the Federated Institution of Mining Engineers and receive the *Transactions*, which are an education in themselves.

The Technical Education Committee was formed as a sort of adjunct to the Staffordshire County Council to carry out the details of the Mining Lecture and Instruction Scheme. Under the chairmanship of Mr. Arthur Sopwith it has arranged the lectures, classes, and examinations, and apportioned the grants to the successful candidates.

The Mining Institute of Scotland has joined the Federated Institution of Mining Engineers, which now includes six societies, viz.: the Chesterfield and Midland Counties Institution of Engineers; the Midland Institute of Mining, Civil, and Mechanical Engineers; the Mining Institute of Scotland; the North of England Institute of Mining and Mechanical Engineers; the North Staffordshire Institute of Mining and Mechanical Engineers; and the South Staffordshire and East Worcestershire Institute of Mining Engineers; with a membership of 1,533 (exclusive of the members of the Mining Institute of Scotland). Meetings have been held in North Staffordshire, Derbyshire, and London, and, as may be seen by the *Transactions*, many valuable papers have been read.

The best thanks of this Institute are due, and are hereby tendered, to the Mason College authorities, for providing rooms for the meetings.

The Council feel that much more might be done by the members in reading papers, introducing new members, and attending the meetings, which would materially conduce to the success of the Institute.

Dr. THE TREASURER IN ACCOUNT WITH THE SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS, FOR THE YEAR AND SEVEN MONTHS ENDING JULY 31ST, 1893. **Cr.**

	£	s.	d.		£	s.	d.
To Bank Balance ...	309	19	5	By Subscription to the Federated Institution of Mining Engineers from January 1st, 1892, to July 31st, 1893	128	7	8
,, Subscriptions Received	253	16	6	,, Secretary's and Reporter's Fees for same period ...	79	3	4
,, Bank Interest ...	8	2	0	,, Printing, Stationery, etc. ...	16	4	10
				,, Expenses in connexion with the Federated Institution of Mining Engineers' Meetings and Annual Meeting and Audit ...	10	13	0
				,, Postages, Telegrams, etc. ...	7	3	0
				,, Subscriptions to the Sir Warington Smyth Memorial ...	5	5	0
				,, Fee to Porter for attendance in connexion with meetings	1	0	0
				,, Charge of Reporters in connexion with Federated Institution of Mining Engineers' visit to Birmingham in September, 1891 ...	4	4	0
				,, Bank Charges ...	0	14	0
				,, Arrears due to Federated Institution of Mining Engineers, and which it was arranged to pay out of the funds to equalize financial years ...	37	2	6
				,, Special call of Federated Institution of Mining Engineers to meet the expenses of the first three years ...	12	5	0
				,, Balance in Bank ...	274	15	7
	£571	17	11		£571	17	11

BALANCE SHEET, 1892-3.

Liabilities.	£	s.	d.	Assets.	£	s.	d.
To Balance ...	352	11	10	By Cash at Bankers ...	274	15	7
				,, Subscriptions due ...	77	16	3
	£352	11	10		£352	11	10

Examined and found correct,

DANIEL ROGERS.
WILLIAM H. WHITEHOUSE.

September 28th, 1893.

This is exclusive of considerably more than £100 worth of property, for which no credit is taken.

The CHAIRMAN moved the adoption of the Reports of the Council and of the Auditors, and the accounts. He congratulated the members on some features in the report, and urged that the requisite means should be taken to improve the voting power of the Institute at the meetings of the Federated Institution of Mining Engineers. At present this was small, and he hoped the members would use the same energy as that exercised by other federated institutions to increase their membership and consequently their voting powers.

Mr. JOHN HUGHES, in seconding the motion, said he supported the suggestion of the Chairman, and added that he could not avoid an expression of regret called forth by that part of the report which referred to the death of Mr. Joseph Cooksey. They all deplored his loss as an eminent mining engineer, as an ex-President of that Institute, and as the father of it at the time of his demise. On another point he could express pleasure, and it was at the fact named in the report that a prize had been awarded to the Chairman and his (Mr. Hughes') son for a paper read before the Federated Institution of Mining Engineers. They could not help regarding it as highly gratifying that they had been chosen to receive that honour.

The reports and accounts were then unanimously adopted.

Mr. W. B. SCOTT, in proposing a hearty vote of thanks to the retiring President, said they would all feel how thoroughly Mr. Clark had earned their grateful acknowledgments. The work in connexion with such an Institute was considerable. Interest had to be kept up, members to be stirred to action, papers to be provided, and discussions arranged for: all those duties belonged to the position, and were the chief care of the President. Mr. Clark had not only done his best to improve the position of their own Institute, but to advance the interests of the Federated Institution of Mining Engineers as well. He had the utmost pleasure in proposing a vote of thanks to the retiring President for his most valuable services during the past eighteen months.

Mr. W. J. HAYWARD, in seconding the motion, said that at the last annual meeting he ventured to predict that Mr. Clark would worthily and ably tread in the footsteps of those who had preceded him in the chair, and there was no one but would fully agree that the prediction had been carried out. The Presidency of Mr. Clark had been one of devotion to the interests of the Institute, and would always be remembered with much gratification.

The motion was then adopted unanimously.

Mr. Clark, in reply, thanked the members very sincerely for the kind resolution they had passed. If he said anything further it would be in reference to their newly elected President. They had secured as President a gentleman who would raise the status of the Institute and be a tower of strength to them when another meeting of the Federated Institution of Mining Engineers was held in their district. When that occurred they would have the proud satisfaction of having one of their members as President of that Institution, and Mr. Claughton at the head of the local Institution. That year had been one of very remarkable interest to societies of mining engineers. They had partially succeeded in accomplishing the ideal of federation, but success was not yet fully ensured. There were still one or two institutes holding aloof, but doubtless they would take in the whole range, and become a really united body all over the kingdom.

Mr. W. H. Whitehouse proposed a vote of thanks to the Council and Officers for their services.

Mr. Gibbs seconded the motion, which was cordially approved.

Mr. Glennie, in returning thanks on behalf of the Council and Officers, said the Council did a great deal of unseen work, and while the Institute was increasing somewhat in numbers, and also in importance, they might well suppose that the work of the Council and Officers was not diminished. A Technical Education Committee had had to be appointed, the President had had a great deal more work to attend to in consequence of their connexion with the Federated Institution of Mining Engineers, and the Secretary and the Treasurer were in the same way affected by an increase in the duties devolving upon them. All of them, however, would be only too proud to give their closest attention to the requirements of the Institute, and to do all they could to promote its interests.

Mr. H. G. Graves then read "A Contribution to the History of Fire-damp":—

A CONTRIBUTION TO THE HISTORY OF FIRE-DAMP.

BY H. G. GRAVES.

INTRODUCTION.

No branch of mining is of greater importance to the welfare of the community than that which deals with the methods employed for obviating the disastrous effects of fire-damp explosions. The question of fire-damp has therefore exercised the minds of many inventors, notably during the past thirty years. A short classified description of the various methods and devices will not, it is thought, be useless or uninteresting. Although the literature of fire-damp is very extensive, there are not many complete accounts of any one part of the subject. Attention, however, may be drawn to a very interesting history of fire-damp in the collieries at Anzin by Mr. A. François,* and to the description of the various detectors brought before the Royal Commission on Accidents in Mines.† To the latter, this paper may be considered in part as a supplement since it contains amongst other things a collection of the records in the numerous specifications filed in the British Patent Office as far as they relate more immediately to fire-damp. The main object has been to collect and classify all the apparatus used for the detection and estimation of fire-damp, but, as in this search, it was found that various improvements, on the method of the fireman, had been patented, these are therefore included together with other methods of destroying fire-damp *in situ*. Also german to this subject is the use of some of the detectors for signalling the condition of the working-places and goaves, and, when pipes are employed for this purpose, their further use for the extraction of gas.

Although very few of the ideas have proved to be of any use, yet a collection such as this illustrates the way in which many minds work and may, in some instances, save others from traversing the same ground. The records of the Patent Office have mainly been relied upon, but the author has not hesitated to use other authorities to a large extent. Many of the specifications quoted in this paper are simply provisional specifications, the applicants having probably seen the error of their ways, and have therefore not completed their applications. In such cases the patent was not granted, but until 1884 these specifications were always printed.

* *Annales des Mines*, series 9, vol. ii., page 233. † Pages 97-107.

During recent years, explosive gases have been generated in other places than in mines, and have to be guarded against. Any place in which coal or oil are stored have to be protected from accumulations of gas, so that much of what follows is of far more general application although fire-damp only has been specially considered.

I.—The Removal of Fire-damp.

In the early days of coal-mining, fire-damp did not cause much trouble, because the workings were very shallow; but in the seventeenth century small explosions were of frequent occurrence, and in October, 1705, the first great disaster took place. Fire-damp was at first supposed, amongst other things, to be a kind of sulphur. Prof. George Sinclair, of Glasgow University, writing in 1672, calls it a fat oily vapour, and describes the fireman at work in the morning. Even at that date, some pits had to be abandoned on account of the prevalence of gas. The only method of overcoming the gas was to fire it before the miners entered the pit, and this was done by a fireman clothed in leather or wet clothes with a lighted candle at the end of a long stick. In France he was known as the "penitent" from the shape of his clothes. To avoid the danger it was necessary to get farther away, and for this purpose several methods were employed.

In one case in the South Wales district, the fireman was paid five shillings a day to examine the workings in a small but fiery mine before the men came to work. "In the different workings to be examined, holes were sunk in the bottom just large enough to allow a man getting in and stooping down. It was his duty to examine every place, and if there was fire-damp, he lighted his candle outside the danger, placed it in clay, sticking the clay on a small board to which was attached a piece of string. He then got into the hole, having on a thick flannel jacket and his head and hands covered also; and having placed a couple of small boards over his head got as low into the hole as he could, and then drew the board with the lighted candle in to him and exploded the gas (lamps were unknown then)."*

In Staffordshire, they used a wire leading from the stables to the heading and back, and carried on posts. The fireman took refuge in the stable, and then hauled a lighted candle weighted so as to keep it upright to the fiery places. In Netherton colliery, this had to be done three times a day about the year 1800.

* *The Last Thirty Years in a Mining District*, 1867, pages 26, 27.

Meanwhile an inventor was busy, and the first patent connected with this subject was granted in 1826 (No. 5348) to Mr. William Wood for a clock-work arrangement which struck matches and ignited the gas at intervals. He also devised wires coated with inflammable substances, and stretched them through the working to convey the flame. Electric apparatus and rockets travelling on wires were suggested by others as late as 1881. In fact the following passage which occurs in a provisional specification in 1880 would show ignorance or else a bad state of affairs in Connecticut:—"When fire-damp or light carburetted hydrogen has accumulated in large quantities in a mine it has heretofore been the custom to vacate the mine and fire the gas. This is attended with great danger . . . as the gas becomes heated and explodes in places." This process was, however, in use as late as 1879, when it produced a disastrous accident at the Bruckenburg mine at Zwickau, after which it was legally abolished there in 1881.

The patent specifications mentioned below are all for various means of igniting the gas *in situ* and do not require further comment:—Wood, No. 5348, 1826; Addison, No. 2727, 1857; Harbert and Goodman, No. 565, 1867; Walker, No. 3091, 1869; Blacklidge, Battle and Willcox, No. 3655, 1880; Budenburg, No. 4227, 1880; and Morgan, No. 719, 1881.

With a view to increasing the safety of this method of procedure, it has been proposed to maintain an incandescent wire in a gauze receptacle through which it is supposed that air can freely circulate, but from which it is supposed that flame cannot escape. Spongy platinum instead of an incandescent wire has also been tried in the Saarbrücken and Westphalia coal-fields, but under the most favourable circumstances the action was exceedingly feeble.

Were it only feasible, a much better plan would be to destroy the gas *in situ* without igniting it. No less than six English patents have been applied for with the end in view of either destroying or neutralizing the gas. The gist of these is given below:—

Jones, No. 2200, 1867. Steam together with cyanides, or oxides, acids, alkalies, etc., a long list being given.

Rogers and Rogers, No. 2609, 1879. Steam "to neutralize the explosive power of the gas."

Daye, No. 2803, 1880. "Applying saturated currents of air to inflammable gases given off by coal to prevent their firing or exploding." "The use of solid inflammable (*sic*) elements such as sand or dust to prevent spreading of combustion in place of using water."

Girard and Pabst, No. 3584, 1881. Lead-chamber crystals from the manufacture of sulphuric acid.

Jenkins and Treherne, No. 5179, 1881. The fumes of a burning mixture of Peruvian bark and tobacco are said to enforce a chemical union of hydrogen and oxygen, and the particles of smoke diffusing through the fire-damp prevent rise of temperature and ignition of gas. The admixture of bark is to prevent its being used as a cloak for surreptitious smoking.

Shehan, No. 2366, 1882. Hydrate of lime and black oxide of manganese or charcoal.

The effect of steam on a practical scale in reducing the explosive power of fire-damp and air is *nil*, and the other proposals are useless. Similar ideas are often propounded, and one sanguine person ingenuously confessed that he had forgotten the chemical composition of gas, but boldly proposed the use of disinfectants. Of a somewhat similar nature is the proposal to stop an explosion by liberating a large quantity of carbonic acid in front of it, means for doing this having been described in some letters to the technical press about two years ago.*

It may be assumed that the only safe way of dealing with fire-damp is to mix it with plenty of air by vigorous ventilation. As an aid to the main ventilation of the mine, small portable fans can be used in the workings to dispel local accumulations of fire-damp. It is also often proposed to deal with the gas and bad air in the mine by a series of pipes connected to a pump at the surface. As however, these pipes are often also intended for obtaining samples of the mine air, this matter will be referred to later in that connexion. Simple blowers of gas can be successfully dealt with by the use of pipes, and several instances might be quoted in which the gas has been collected and used in the ventilating furnaces, or for generating steam and other purposes at the surface, for a considerable period. At Wallsend, to mention one example, a blower giving 120 cubic feet of gas per minute was used for some years.

II.—Detection and Estimation.

Nearly all the proposals that have been made for the detection and estimation of fire-damp may be considered under three classes according to the method of action:—(A) gravimetric; (B) diffusion; and (C) combustion.

There are, however, a few nondescript proposals which should be mentioned to make the description more complete, although they are in some cases absurd almost beyond belief.

* *Colliery Guardian*, vol. lxi., January to March, 1891.

The requirements of a detector are that it shall give good results under all conditions, that it shall be portable and convenient in use, and that it shall be safe. At the same time it is preferable that it should serve as a lamp or at least be combined with one.

(*A*) *Gravimetric Methods.*

The several devices which are included under this head depend on the difference in density between ordinary air and air in admixture with fire-damp. The ratio of the density of pure marsh gas to air is 0·55 to 1, but the absolute weight of any volume with which it is possible to work is so small that great accuracy of measurement under most perfect conditions is required to obtain results of any value. In gas-works, apparatus of this nature is in general use for the determination of the density of the gas, but the work is done in a carefully appointed laboratory. A glass ball, some 6 inches in diameter, is mounted at one end of a counterpoised balance beam, and a continuous stream of gas is led into it. Any change in the density of the gas is at once indicated by a movement of the beam, and this movement may work a continuously recording instrument.

This type of apparatus is one that is frequently proposed. A simpler form of it consists merely of a balloon filled with gas of such density that it will sink when the fire-damp contents of the air rise to a predetermined limit. Another consists in the adaptation of a hydrometer, which is made with the part above the water greatly enlarged, so that it sinks when the density of the air decreases.

The use of an aneroid or other barometer has also been suggested. One example of this deserves further mention. In patent No. 304, 1872, a long vertical tube, 107 fathoms long, is filled with the air from the mine, and the density is measured by an inclined water-gauge.

Continuously recording barometers or barographs might be mentioned in this connexion, and patent No. 9857 of 1885 describes one especially adapted for colliery use to signal rise or fall.

In the before mentioned methods, the weight of the air is directly measured, but its density may be determined indirectly by means of a musical note as in the "damposcope" invented by Prof. George Forbes (No. 3261, 1879). A tuning fork is placed over the mouth of an adjustable resonator, consisting of a tube in which slides a piston connected to a pointer. The piston is adjusted to give the maximum resonance. A thermometer is attached, and has its scale graduated with calculated numbers, which are subtracted from the pointer indications to allow for

temperature. This apparatus was further modified by the inventor and Mr. Blaikley, as it was found that the point of maximum resonance could not easily be determined. In the second apparatus observations were made of the beats of two sounds nearly in unison. A free reed is fixed at the otherwise closed end of a tube, so that the notes from the air column in the tube and from the reed synchronize. If the density of the air in the tube has changed the note is changed, and when sounded in comparison with the original note will cause beats. These can be counted, or the length of the tube can be altered to again synchronize the notes.

Another musical device, but depending on the lengthening of a hydrogen flame is described by Mr. Somzee (No. 2073, 1881).

In another indirect method, either carbonic acid or hydrogen as required is mixed with a sample of the air until it is brought to the same density as the atmospheric air. Mr. Young's patent, No. 4410, 1879, describes means for doing this, fumes of ammonium chloride being employed as an indicator.

The results obtained from all these apparatus are more or less inaccurate on account of the varying temperature and pressure, and of the varying amount of moisture and carbonic acid in the air. It is not possible to easily allow for these conditions, but Mr. Egger, in patent No. 7846, 1891, proposes to overcome the difficulties by making the balloon or balance globe partly or entirely flexible. In Mr. H. G. Carleton's apparatus* attempts are also made to overcome the difficulties incidental to moisture in the air, etc. The apparatus is necessarily so large and delicate that it is quite unsuited for use in a mine. The "damposcope" and its modifications can be made compact enough, and, though it requires all the corrections mentioned above, yet it deserves especial mention on account of the ingenuity exhibited.

A list of the specifications follows:—Warwick, No. 9282, 1842; Beaumont, No. 867, 1857; Addison, No. 2727, 1857; Gisborne & Wickens, No. 633, 1862; Moore, No. 1404, 1862; Ansell, No. 668, 1865; Young, No. 304, 1879; Forbes, No. 3261, 1879; Young, No. 4010, 1879; Budenburg, No. 1377, 1880; Budenburg, No. 4227, 1880; Macdonald, No. 4680, 1881; Bella & Challoner, No. 15694, 1884; Swan, No. 11928, 1887; Molas, No. 12313, 1888; and Egger, No. 7846, 1891.

(*B*) *Diffusion Methods.*

Under this head are included those devices which depend for their action on the diffusion of gas through porous diaphragms. The law of

* *Engineering and Mining Journal* (New York), vol. xli., page 265.

diffusion is that the ratio is inversely proportional to the square root of the density. Accordingly if a porous vessel full of pure air be placed in an atmosphere of fire-damp, the latter, which is the lighter, will pass into the vessel faster than the air can emerge and consequently the pressure inside will be raised. This pressure can be measured in many different ways and the amount of fire-damp in the air deduced. Another system is to use some means for analysing the gaseous mixture in the vessel.

Several materials may be employed to form a porous diaphragm or vessel suitable for use in such apparatus. Messrs. Roscoe and Schorlemmer recommend graphite. Plaster of Paris or unglazed porcelain can also be used. The chief thing is that the porous layer should be as thin as possible to facilitate the action.

The pressure is measured by means of a liquid column, by the deflection of a thin diaphragm as in the aneroid barometer, or by a coiled tube as in the Bourdon pressure-gauge. As the pressure is small, the apparatus must be delicate, but the movement obtained by the use of the diaphragm or other means may easily be magnified by a pointer or in any other well known manner. There is still another way of utilizing diffusion apparatus, and that is to concentrate the gas by its aid, and to analyse or otherwise test it. For this purpose, amongst others, the use of spongy platinum inside the diffusion-chamber has been proposed. The action of this is referred to below.

The apparatus should be placed so that the air to be tested is constantly renewed, and then the indicator will, to a certain extent, follow the fluctuations in the percentage of fire-damp.

The same disadvantages that have been mentioned as applying to gravimetric methods, apply also here. Any change of atmospheric pressure or temperature will raise the pressure inside the vessel and give false indications. The action of the apparatus is slow at the best of times, and is rendered slower by any dust or moisture that collects on the porous material. Wet may be excluded, but a shield of cotton wool, to prevent the access of dust, also prevents free circulation of air.

The following list gives the numbers of the specifications of the several apparatus under this class:—Ansell, No. 668, 1865; Webster, 3993, 1876; Aitken, No. 963, 1880; Somzee, No. 2073, 1881; Libin, No. 87, 1883; Wolf, No. 6348, 1889; and Stern & Kaufmann, No. 13668, 1889.

(*C*) *Combustion Methods.*

This class is the most important and has perhaps been the most thoroughly investigated. It includes all those devices in which the fire-

damp or other carburetted gas is burnt, and may be considered under three distinct sub-divisions :—First, slow combustion by the aid of substances like spongy platinum ; second, slow combustion and ignition by an incandescent wire or electric spark ; third, combustion aided by a safety-lamp flame or like means.

(*a*) *Spongy Platinum Methods.*—Spongy platinum has the power of absorbing or condensing hydrogen, carburetted hydrogen, and other gases, and, by what may be termed a catalytic action, bringing them into closer contact with the oxygen of the air. Chemical combination is thus promoted, and the temperature rises. In some cases the action is so intense that flame is produced, but in a dilute gaseous mixture there is simply a moderate heating. Other bodies besides spongy platinum have this property, and amongst these may be mentioned platinum black and also palladium, rhodium, osmium, and iridium, especially when in a finely divided state or as oxides. If these substances are first slightly warmed, say to 80 degs. C., the reaction is facilitated. The fineness of division is also an important factor. Asbestos soaked in platinum oxalate and ignited has been recommended by Mr. H. W. Warren, who states that, when previously heated, it will become incandescent in air containing 0·5 per cent. of coal-gas.

The rise of temperature thus obtained forms a means for determining the percentage of gas pr sent in the air, and it is to the means used for measuring this temperature that so much invention has been directed. The temperature can be measured directly by means of a thermometer, or the rise of temperature can be obtained by a differential thermometer. A thermopile has also been used. The increased electrical resistance due to the heating of a wire coated with these materials, or the expansion of a rod similarly covered may form a basis for the measurement. If the material is placed in a closed vessel filled with the air to be tested, the increase of pressure due to heat can be observed or the material may be used in a eudiometer instead of the electric spark. In fact any means that can be used to determine temperature may also be employed, and there would thus appear to be an endless field for further development into automatic recording instruments or alarm arrangements. Unfortunately this spongy platinum and the other metals soon lose their power of causing the slow combustion of gas. Moreover the expense and difficulty of the application of such fragile substances quickly sets a limit to their use.

Dr. Angus Smith proposed the use of platinum black in a hand air-compression syringe. When air containing 2·5 per cent. is thus compressed,

an explosion will take place. If 5 per cent. is present, no platinum black need be used, as the rise of temperature due to compression is then sufficient to cause ignition. The apparatus is considered to be dangerous and has but limited range.

The oxides have also been applied by Mr. J. Aitkin (No. 963, 1880), who uses their reduction to a metallic state by gas to complete an electric circuit.

A list of the various inventors is given below:—Maurice, No. 3905, 1878; Körner, No. 579, 1879; Körner, No. 705, 1880; Aitkin, No. 963, 1880; Perry, No. 12636, 1886; Pitkin and Niblet, No. 4629, 1889; and Pitkin and Niblet, No. 11101, 1890.

(*b*) *Photometric and Analytical Methods.*—The second subdivision of this class includes all those devices in which combustion is caused by wire heated by the electric current, or by another source of heat sufficient to cause combustion or explosion, but not including safety-lamps. It therefore embraces all the modifications of the Liveing apparatus, and also the more or less purely analytical methods. As the methods of measurement are applicable in part to both these varieties, they are considered together.

The idea that underlies all these devices consists in utilizing either the heat, the increase of volume, or the pressure generated by the combustion or explosion of the gas as an indication. The Liveing indicator is one of the best known adaptations of this idea. It practically consists of two platinum spirals rendered incandescent by an electric current, one of these wires being enclosed in pure air whilst the other is open to the air to be tested. If gas is present it burns and raises the temperature of the wire to which it has access, so that the wire is rendered more luminous. The difference of luminosity is ascertained by a photometer, and from the difference the percentage of gas present may be found. In his patent (No. 4833, 1880) the inventor furnishes directions for making the spirals. Prof. Clowes* gives the results of tests made with the apparatus by Mr. J. Grundy, and mentions a well-known drawback, that the spirals deteriorate and break after some use.

In modifications of the Liveing apparatus, instead of comparing the luminosity, the difference of temperature is observed by means of a differential thermometer, or the radiation may be measured by a thermopile, or the increased resistance of the wire may be measured directly or compared with that of the other wire by means of a Wheatstone bridge. In the latest two wire apparatus (Murday, No. 19856, 1890) the difference of expansion is measured by a system of wires and levers. The exposed wire

* *Journal of the Society of Arts*, vol. xli., page 310.

is sometimes used without the second or comparison wire, and the increase of luminosity judged by the eye or the indications are taken by any of the methods previously described.*

Development in the other direction under this subdivision leads to apparatus closely akin to that ordinarily used for gas analysis. The Coquillion "grisoumètre," the Monnier "méthanomètre," and the Maurice apparatus are really forms of eudiometers. A sample of the air to be tested is burnt in the tube by means of a wire rendered incandescent by an electric current, and as soon as the gases are cooled the contraction in bulk is measured. Sir W. T. Lewis and Mr. A. H. Maurice,† in describing the Maurice apparatus, state that it takes two minutes to completely burn the gas, but that exactly half is consumed in 14 seconds. In most of these devices the pressure is measured by a liquid column; but it is obvious that any other means may be employed for the purpose, as was mentioned when dealing with diffusion apparatus. By combustion in a separate chamber the time required for cooling can be diminished, as in the Von Mertens modification. In using such apparatus care must be taken that fire-damp is not in excess, as there would not then be sufficient oxygen for complete combustion, and wrong indications would be given.

Both of these two types of apparatus can be constructed so as to be portable, and can also be attached to a miner's electric lamp. Of all the various forms of detectors, with the exception of safety-lamps, they are the only ones really in practical use, and in skilled hands they give trustworthy results.

There is one other device that merits special attention under this part of the subject as it is analytical in its action. This is the Shaw indicator, described in patents Nos. 3531 and 11928 of 1887. In many of the American papers an acrimonious discussion raged over it, chiefly on account of the claim that a system of pipes could also be used with it to enable samples to be taken from any part of the mine, or for signalling purposes, or even for supplying entombed miners with food. The apparatus was, however, admitted to be good for analysis of samples of air in a laboratory. It acts on the principle of mixing the sample with air or gas to produce a mixture which will explode when brought into contact with a flame. For this purpose a definite quantity of the sample is mixed with varying amounts of air by means of two pumps with their pistons actuated from one beam, one of the pistons is adjustable on the beam so as to vary its stroke, and from its position the percentage of admixture can be read off.

* *Trans. Fed. Inst.*, vol. ., page 469.

† *Trans. North of Eng. Inst.*, vol. xxxvi., page 73.

As it seemed doubtful whether the explosive point could be accurately determined, Mr. H. le Chatelier* made some experiments that showed that this could be approximately done. At the same time he designed a very simple apparatus for this work, and his device has since been used to a considerable extent in France, amongst others by Mr. L. Poussigue† at the Ronchamp collieries. It simply consists of an eudiometer tube, the upper portion of which is contracted in diameter and graduated.

For strictly accurate results any of the numerous forms of gas-analysis apparatus may be used, but the forms mentioned above are sufficiently accurate for practical purposes. It may be useful to state that the Coquillion "grisoumètre," one of the eudiometric type, was thoroughly investigated by Mr. Castel,‡ and a modified form is in daily use at the Karwin collieries in Austrian-Silesia according to Mr. P. von Mertens.§ Fuller details of these types of apparatus will be found in a paper contributed by Mr. G. Chesneau to the International Engineering Congress, Chicago, 1893.

The list of British specifications given below will show that numerous inventors have been busy with these forms of apparatus, the salient features of which have been described above :—Moore, No. 1404, 1862 ; Coquillion, No. 1171, 1877 ; Higgins, No. 648, 1879 ; Cougnet, No. 2000, 1879 ; Aitkin, No. 963, 1880 ; Laurent, No. 1101, 1880 ; Liveing, No. 4833, 1880 ; Monnier, No. 312, 1881 ; Kitsee, No. 3644, 1882 ; Maurice, No. 12089, 1884 ; Kitsee, No. 8631, 1885 ; Swan, No. 1999, 1886 ; Swan, No. 3362, 1886 ; Shaw, No. 3531, 1887 ; Schanschieff, No. 6028, 1887 ; Swan, No. 11928, 1887 ; Maquay, No. 14932, 1888 ; Shaw, No. 18105, 1888 ; and Murday, No. 19856, 1890.

(c) *Safety-lamps.*—The ordinary way of testing is, of course, by the safety-lamp, but it is not intended to discuss here the various forms that are in general use.

In a paper on safety-lamps by Mr. W. H. Hughes,‖ his experience with several forms is given. The latest form of the Hepplewhite-Gray lamp is there recommended for testing purposes, and next to that the Mueseler is stated to be most efficient. In connexion with safety-lamps however there are two or three things that may be mentioned. The Garforth ball, patent No. 8500, 1884, has been a useful adjunct to lamps for testing air near the roof, but several lamps are now made to take their air-supply from the top. In patent No. 103, 1881, Mr. Hackworth describes an

* *Annales des Mines*, series 9, vol. xix., page 388.

† *Bulletin de la Société de l'Industrie Minérale*, series 3, vol. vi., page 249.

‡ *Annales des Mines*, 7th series, vol. xx., page 509.

§ *Zeitschr. f. anal. Chemie*, vol. xxvi., page 42.

‖ *Trans. Fed. Inst.*, vol. i., page 255.

inverted syphon with the shorter limb heated in order to draw down the roof gas, and in patent No. 4488, 1879, Mr. Jones describes a pump which may be made in the form of a walking-stick for the purpose of gathering samples as is done by the Garforth ball. A similar device to that of Mr. Garforth was made by Mr. Lechien.* Messrs. Redwood, Clowes, and Waters in their latest patent, No. 187 of 1893, also describe several forms of sampling-pumps for use with the hydrogen-flame lamp.

One or two inventors do not trust to the eyes for seeing the cap. Mr. Irvine, patent No. 1896, 1871, for instance surrounds the flame by a tube so that it roars if gas is present, and a similar arrangement with a hydrogen-flame is mentioned by Mr. Somzee, patent No. 2073, 1881. Pyrometric devices or other means for making an electric circuit, or otherwise giving an alarm, have also been introduced into the lamp, one of these being a thread above the flame which is burnt through when the flame elongates. In the Hyde lamp the thread when it breaks allows shutters to fall and cut off the air-supply.

There are, however, a few special forms of lamp which differ from ordinary lamps and require special mention. These are the Pieler spirit lamp, the Chesneau alcohol lamp, the Clowes hydrogen-flame, and the Stoker lamp with alcohol-flame. The first is so well known that it does not require further description.

The Chesneau lamp† is a modification of the Fumat lamp designed to burn alcohol and to overcome some of the danger in the use of the Pieler lamp. The air-supply enters at the base through a double gauze, which can be closed by a shield. A sheet-metal cylinder surrounds the wick tube and serves as a shade. The gauze is somewhat conical, and is surrounded by a shield pierced by a window for observation. It is found that the height of the cap and the flame depends considerably on the nature of the spirit employed. The use of metallic salts to render the flame more distinct was experimented with, and it was found that the addition of cupric chloride was advantageous, giving a uniform green tint. This salt is soluble in alcohol, and is used to the extent of thirty drops of a concentrated solution in strong hydrochloric acid per litre. The height of the wick is adjusted by a regulating screw, and to ensure, as far as possible, the same temperature, the lamp is allowed to burn about a quarter of an hour with the wick high. The tests should be made as quickly as possible, or else the lamp gets hot from the combustion of the gas, and the

* *Mémoires de la Société des Ingénieurs Civils*, vol. xxxix., page 641.

† *Annales des Mines*, series 9, vol. ii., page 203; *Trans. Am. Inst. Min. Eng.*, 1893.

flame suffers an excess elongation. Mr. Chesneau has found that variations of the carbonic acid and temperature of the air do not much affect the height of the cone when gas is present up to 2½ per cent., although the luminosity is affected*.

Prof. Clowes' lamp has recently been described by him† before this and other societies so that a reference to it is alone necessary. It may be mentioned that his name appears on two patents, No. 6051, 1892, and No. 187, 1893, in the latter, together with Mr. Boverton Redwood and Mr. Waters. In that patent a form of the lamp for use above ground is described.

In the Stokes' lamp, the hydrogen-flame of the Clowes' lamp is replaced by an alcohol-flame, and the arrangement appears to be lighter, more simple and cheaper.‡

The principal patents relating to this subject are given below:— Irvine, No. 1896, 1871; Jones, No. 4488, 1879; Brunton, No. 4754, 1879; Körner, No. 705, 1880; Laurent, No. 1101, 1880; Hackworth, No. 103, 1881; Somzee, No. 2073, 1881; Garforth, No. 8500, 1884; Macnab, No. 13590, 1886; Howat, No. 7749, 1890; Ashworth, No. 18918, 1890; Heys, No. 934, 1891; Ashworth and Clowes, No. 6051, 1892; Redwood, Clowes and Waters, No. 187, 1893; and Stokes, No. 6363, 1893.

(*D*) *Miscellaneous Detectors.*

There are one or two courses for the determination of fire-damp that cannot properly be included under the foregoing headings. For instance, in the patent application No. 2073, 1881, Mr. Somzee suggests the action of chlorine on marsh gas under the effect of a strong light, and also the elongation of a hydrogen-flame causing a sensitive reed-pipe to sound. Dr. Angus Smith's compression-syringe is also to be noted here. Under this miscellaneous heading Mr. I. F. Nowack's sensitive plant (*Abrus precatorius*) is included. Much used to be heard of its value as a prophet of weather and earthquakes. One of its many properties was said to be a power of indicating and foretelling fire-damp and explosions. It would be a curious thing to know, too, if the divining-rod has ever been used for this purpose. The records, if any, are hard to find. Several persons more ingenious than wise have proposed that men of keen scent should be employed to find fire-damp, but they should read Mr. Downey's tale of "The Land Smeller."

* *Trans. Fed. Inst.*, vol. iv., page 617.

† *Trans. Fed. Inst.*, vol. iv., page 441; *Journal of the Society of Arts*, vol. xli., page 307.

‡ *Trans. Fed. Inst.* vol. v., page 462..

III.—Signalling.

In the foregoing account of indicators, no particular mention has been made of signalling devices operated by them. Many of the forms are, however, adapted for giving some kind of alarm when the percentage of fire-damp rises above a predetermined limit. Some of them telegraph the varying percentage whatever it may be, and are intended to be quite automatic for they are scattered through the pit and are connected to the office above ground. Electric communication has found most favour, but in those cases where a system of pipes is used for drawing samples of air from different localities, as in the Shaw arrangement for instance, these pipes are used as speaking-tubes or for pneumatic signalling of some kind. In electric signalling, except in special cases, at least one wire is required for each instrument, but sometimes the arrangement requires several conductors. The motion of some part of the indicator, such as a pointer moving over contacts, or a mercury column, closes one or more electric circuits and rings a bell, lights an incandescent lamp, or gives some other signal either directly or through a relay circuit. In some instances a change of electric resistance induced by the increase of heat in the detector or by the motion of mercury column, etc., is used to vary the current and so operate signals. Selective signals have also been applied, that is, all the detectors are in one circuit and the registering office is enabled to show not only the amount of fire-damp, but also to show the particular detector which has been disturbed. An interesting summary of selective signalling has been given by Mr. T. D. Lockwood,* which shows that the systems proposed are still in their infancy.

In connexion with one or two indicators, the inventors have mentioned continuous automatic recording-instruments more or less on the principle of the barograph. Mention might also be made in this connexion of a patent, No. 9857 of 1885, granted to Mr. R. Ritter von Walcher-Uysdal for a special form of barometer intended for colliery use. A clockwork alarm is attached to show the amount of fall in the preceding eight hours, but no alarm is given when the pressure rises.

It would be useless to give a complete list of all the patent specifications in which signalling is mentioned in connexion with the indicators, as the sole description is often confined to a hint of the means employed, and the bare outline just given contains as much information as the patents themselves. In fact most of the patentees state that signalling devices may be employed in connexion with their apparatus. There are,

* *Trans. Am. Inst. Electrical Eng.*, vol. ix., page 525.

however, some exceptions which give a more or less complete description of signalling arrangements, and these may be consulted in conjunction with Mr. Lockwood's paper.

The more important of these specifications are as follows :—Webster, No. 3993, 1876 ; Körner, No. 579, 1879 ; Aitkin, No. 963, 1880 ; Monnier, No. 312, 1881 ; Kitsee, No. 3644, 1882 ; Libin, No. 87, 1883 ; Kitsee, No. 8631, 1885 ; von Walcher-Uysdal, No. 9857, 1885 ; Perry, No. 12636, 1886 ; Shaw, No. 3531, 1887 ; Shaw, No. 18105, 1888 ; Pitkin and Niblet, No. 11101, 1890 ; and Egger, No. 7846, 1891.

IV.—Sampling and Drawing-off Gas.

As it is convenient on some occasions to test the mine air in the laboratory, it becomes necessary to take samples of the air from different localities in the mine. The Garforth ball and the Jones walking-stick pump have already been mentioned, and also the Lechien ball and the devices in the last patent granted to Messrs. Clowes, Redwood, and Waters, No. 187 of 1893.

The use of a system of pipes is a favourite method and dates back to an early period. Suggestions made to the French Fire-damp Commission* contain this idea over and over again. Not only are these pipes suggested for sampling purposes, but it is frequently proposed to carry out the entire ventilation of the mine by their aid. Some extensive experiments were made at the König colliery, Grevenberg, near Aachen, by Mr. Hilt to determine the possibilities of this method, and these have been described by Mr. H. Brenner.† At this colliery the seam varies from 6 to 6½ feet in thickness, and from 20 degs. to 50 degs. in dip. A bord-and-pillar system of working is used and arranged so as to carry the air well up to the working-face. A disused air-compressor was altered so as to exhaust at the rate of about 244,000 cubic feet per 24 hours. From the engine a pipe, 3¾ inches in diameter, was carried down the pit, and for a distance of 1,300 yards, when it branched off in 2 inches pipes for about 300 yards. Finally, pipes of 1 inch bore were led into the working and terminated in perforated rose-ends or boxes covered with wire-gauze placed near the roof. Gauges showed a vacuum of 9¼ inches of water near the pit-bottom. This fell to 1·58 inches at the end of the main, and down to 1·58 inches to 0·08 inch at the suction openings. A steam jet-exhauster was used, but with less success. The

* *Colliery Guardian*, January 16th, 1891, page 103.

† *Zeitschr. f. d. Berg-, Hütten-u. Salinen-Wesen im Preuss. Staate*, vol. xxxvii., page 70.

gases were exhausted alternately into one of two gas-holders at first, but afterwards they were sent directly to the delivery-pipe. On the whole, the experiments were decidedly unsuccessful, as the gas varied so greatly, and so much attention was required to keep the pipes and roses in order. The gases were used under boilers, but without appreciable economy.

Mr. G. McPherson* proposed to insert drainage-pipes into holes bored in the coal and to suck out the gas. This was also suggested by Mr. Faulkner in 1869.

The list of specifications given below includes the various devices used both for sampling and for draining the gas:—Faulkner, No. 2775, 1869; Lemaire-Douchy, No. 2107, 1876; Amoroux, No. 3918, 1879; Jones, No. 4488, 1879; Wodiczka, No. 5160, 1880; Hackworth, No. 103, 1881; Heath, No. 6137, 1884; Garforth, No. 8500, 1884; Shaw, No. 3531, 1887; and Shaw, No. 18105, 1888.

V.—Conclusion.

Many of the methods and apparatus here described have not come into practical use. In some cases this is, it must be admitted, on account of their utter absurdity. On the other hand, many good ideas have not been turned to account, because of difficulties which stood in the way. Sometimes these arose from expense, sometimes from their innate inapplicability to the conditions of the work, and sometimes from unforeseen or unappreciated physical causes that interfered. The inventor, however, is always busy seeking new ways to overcome old difficulties or introducing things that are entirely new. Unfortunately, an inventor, when he is struck with an idea, often proceeds to elaborate it without seeking to find out what has already been done, thereby wasting not only his own time but also that of others. One of the most familiar examples of this is in the proposal to use a series of pipes to drain the gas from a mine. Of course, many good inventions have fallen flat because they have come before their time, but when they reappear, they must be carefully examined under the conditions obtaining at the later date, and the causes of previous failure should be investigated. This paper, the author would, in conclusion, again point out, is intended to give aid on these points, and he hopes that it may be found not only interesting but also useful.

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* *Trans. Min. Inst. Scot.*, vol. ix., page 138.

DISCUSSION UPON MR. A. H. STOKES' PAPER ON "A SAFETY-LAMP WITH STANDARD ALCOHOL-FLAME ADJUSTMENT," ETC.*

Mr. W. B. Scott exhibited Mr. A. H. Stokes' arrangement of a safety-lamp with standard alcohol-flame adjustment for the detection of small percentages of inflammable gas. He said it was capable of measuring as little as ½ per cent. of gas. The application appeared to him to be thoroughly simple; it was reasonable in price, and could be conveniently carried about.

Mr. A. Sopwith said he admired the simplicity of the arrangements of Mr. Stokes' lamp, and considered that it would indicate as small a percentage of gas as was really necessary. Many of the indicators which had been designed for this purpose were of scientific interest, but useless in practice, and he had one in his possession which registered an alarming percentage of gas when taken out into the open air. (Cannock Chase air appeared to be highly inflammable!) Some of the indicators did perhaps approach a practical standard, but there was either a tendency for them to get out of order, or they required very great delicacy in handling and practised powers of observation. In the latter respect, however, it had been distinctly stated by Messrs. Mallard and Le Chatelier that by simple observation and practice, and with the assistance of a magnifying glass, it was possible to determine ¼ per cent. of gas in a lamp simply fitted with a blackened shield. Such close determination would probably be impracticable for most observers, but the statement pointed out the close approach that could be made with an ordinary lamp, though it required nearly as much delicate observation as requisite for the indicators alluded to. He thought that both the Clowes and Stokes lamps were valuable instruments for the detection of gas, and that the Stokes' lamp was especially valuable on account of its simplicity and self-contained construction.

After further discussion, several gentlemen were asked to make tests with these lamps, and to report to a future meeting.

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* *Trans. Fed. Inst.*, vol. v., page 462.

Mr. HENRY JOHNSON then read a paper on "Tamping and Ramming Boreholes," which will appear hereafter in the *Transactions*.

On the motion of the CHAIRMAN, votes of thanks were passed to Mr. Graves and Mr. Johnson for their papers, and the meeting closed.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING,

AT THE MANCHESTER SHIP CANAL WORKS, AUGUST 26TH, 1893.

THE MANCHESTER SHIP CANAL.*

The total length of the canal is 35½ miles, and the completed portion open to the Mersey is about 12 miles—from Eastham to Saltport. The average width of the canal at water-level is 172 feet, the minimum width at the bottom 120 feet, with a minimum depth of 26 feet.

In the earlier stages of this gigantic undertaking there were 100 steam excavators, 173 locomotive engines, 182 other engines, 194 steam and other cranes, 212 steam pumps, over 6,000 waggons, and 15,500 men and boys employed, and the consumption of coal reached 10,000 tons monthly. This day only one locomotive engine was seen in connexion with the canal between Eastham and Saltport, and it was engaged in drawing three or four open trucks containing workmen.

The average width of the canal is 172 feet, but at the locks the width is much increased, and will admit of vessels turning. Large steamers may pass each other at any part of the canal, and works are constructed so that shipping can lie at the wharves without interfering with the ordinary traffic.

The total excavation has exceeded 50 million cubic yards, 10 million cubic yards of it being sandstone rock.

The entrance to the canal from the Mersey is a little above the Eastham pier. During the tides above the ordinary level of the canal, the Eastham lock-gates are open for a considerable time before high water. Spring tides rise to 7 feet above the ordinary level of the tidal portion of the canal.

The gates of the locks are worked by hydraulic power, and move easily. The entrance consists of three locks capable of accommodating all classes of vessels. The locks run parallel to the river bank, the masonry being partly concrete, partly concrete faced with bricks, and partly of red sandstone. The largest of the locks, which is on the south side, is 600 feet long by 80 feet wide; the middle one 350 feet long by

* *Trans. Fed. Inst.*, vol. iii., page 79.

150 feet wide; and the smallest one nearest the river, 150 feet long by 30 feet wide. Between each there is a concrete pier 30 feet wide. Besides the ordinary lock-gates, which are opened and closed each tide, there is for each lock an extra pair of storm-gates, to be closed only at such times as rough weather may render necessary. The largest gates are each 40 feet wide, built of three sets of segments joined together by upright posts, and strengthened by stout timbers running the whole width, by strong steel straps, and a steel rod placed diagonally across each gate, the largest pair of which gates weigh 500 tons. All the gates are constructed of greenheart wood from British Guiana.

At Eastham, in addition to the locks, there are two sluices, each 20 feet wide, also three weirs, each 600 feet long, constructed on the embankment, to allow of the flow of the tide into and out of the estuary portion of the canal when the tide rises above the ordinary water-level of 14 feet 2 inches above the old dock sill at Liverpool, which is about the level of mean high-water.

Every vessel that can cross the Mersey bar at any state of the tide can, without delay, proceed up and enter the canal without stopping for want of depth of water.

The Eastham section, which has been opened for traffic for less than two years, has already developed a considerable amount of industrial activity. Ellesmere Port, the terminus of the Shropshire Union Canal, promises to increase in importance very rapidly.

The floating graving-dock for the repair of ships which may meet with any mishap in the canal, is situated at Ellesmere. The huge pontoon was built on the river Tyne. This floating graving-dock is an enormous tank divided into water-tight compartments capable of being filled or emptied by steam pumps. When it is proposed to admit a vessel the compartments are filled and the dock sinks as deep as may be necessary. The vessel to be repaired having entered, the compartments are then pumped dry, and the whole rises gradually, so that the vessel is as easy to get at as if she were placed in an ordinary dry dock. Similar floating docks have been in use in different parts of the world for about thirty years.

Saltport has sprung up with remarkable rapidity. Eighteen months ago it did not exist even in name; now vessels arrive almost daily from foreign ports, and steamers sail for London and Glasgow with cargoes of Manchester goods.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, SEPTEMBER 18TH, 1893.

MR. ROBERT H. COLE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

DISCUSSION ON MESSRS. LOCKETT AND GOUGH'S PAPER ON "THE LOCKETT AND GOUGH DIRECT-ACTING PUMP."*

Mr. THOMAS LOCKETT said Mr. Treglown had asked what advantage he claimed for this over an ordinary pump? The answer to that question was that he claimed certainty in action, both of steam cylinder and pump. He was prepared to work his model against any other of the same dimensions. It offered no resistance to atmospheric pressure, consequently it must work more solidly. Mr. Treglown was in favour of a pause at the end of each stroke; but his (Mr. Lockett's) knowledge of pumps led him to think to the contrary. He came to the conclusion that if the valve were closed instantaneously the pump would work more solidly, and it would pump more water. Mr. E. B. Wain had asked what was the difference between this and the Hathorne-Davy pump? There was a good deal of difference, and, in fact, there was no resemblance whatever. Mr. Treglown had asked him if he claimed any improvement as regarded the pause at the end of each stroke, when compared with the common direct-acting pump. He did not claim that improvement. Mr. Treglown also raised objections to his model on the ground that the construction was too complicated. He (Mr. Lockett) said, suppose the Tangye cylinder for instance be taken, which is worked with tappet-valves that are liable to get out of order. In the place of tappet-valves, he used plain rods which could not fail to work and were easy to manipulate, so that the stroke of the piston could be regulated to any desired length. If there were any complication it was in sight and easy to get at. Mr. Treglown said "The specifica-

* *Trans. Fed. Inst.*, vol. v., page 431.

tions seemed to embrace some points of other well-known direct-acting pumps, but until the pump was made and worked under fairly average conditions, it would be premature to pass any conclusive opinion on it."* He did not see the necessity for this remark after the opinions that had been expressed. It was very evident that with a pause at the end of each stroke there was a certain amount of water lost. Provided the valves would always act and everything was right there would not be any loss; but it was not very often they could ensure these conditions in pumping water. Mr. Treglown said "inventors ought to be encouraged," but he did not give them much encouragement.

Mr. B. Woodworth said he was still convinced that the pause at the end of each stroke would conduce very greatly to the durability of the pump, and lead to an improvement in the working and durability of the valves. In single-acting pumps, if they were not allowed to settle on the water it might cause a knock; but he could not see how a knock was going to be caused by the pause at the end of each stroke in a properly constructed pump. There were many direct-acting pumps quite certain in their action, but very few that had a satisfactory arrangement for securing a pause at the end of each stroke.

Mr. Lockett said if a pump had such a pause the slide-valve returned suddenly, and there was the same rush of the piston rod as if there was no pause at all.

Mr. Woodworth expressed dissent from this view.

Mr. Lockett remarked that all piston-moved valves must be moved instantaneously.

Mr. Woodworth said there was a limit of time (that would be appreciable in a large pump with Mr. Lockett's gear) consumed in its movements from the main-piston through the tappet-gear and auxiliary-cylinder to the main slide-valve.

Mr. Lockett observed that Mr. Treglown told them that the pump was a complicated one, but it could be adjusted to anything, and it could be worked three-quarter stroke.

Mr. Woodworth mentioned that there was no cushioning.

Mr. Lockett considered cushioning was only a waste of steam.

Mr. Brunt said it seemed to him to be a question of set or no set. Last week he saw a pump with a very considerable and distinct set at a colliery in North Wales, pumping 10,000 gallons per hour against a head of about 500 feet, and making about the same amount of noise as this little model did when it was working. He had seen another working in North

* *Trans. Fed. Inst.*, vol. v., page 441.

Staffordshire against a pressure of 50 or 60 pounds per square inch, and making still less noise. Noise in a pump indicated self-destruction; noiselessness, intrinsic excellence. He was of opinion that a properly constructed pump did not act directly upon the body of water in the delivery-pipe, but through the medium of compressed air; and although the pump might and certainly should stop or set every stroke, and so give time for the water-valves to close, the air maintained a constant flow in the delivery-pipe, and a sort of easy swinging motion went on between the pump and the compressed air-vessel. When these conditions were provided for and secured there was no shock or noise or waste of power, whereas generally there were all three losses in pumps that did not set, because they struck before the water-valves were closed. The set in a direct-acting pump was a very good thing, and lengthened the life of the pump more than anything else, except keeping it clean. It would be a greater improvement still to construct a colliery-pump that would stop altogether whenever anything went wrong with the valves or inlet-flow. Such a pump would work in safety when left alone, and could not knock itself to pieces by running away. The weight or pressure of the atmosphere might be relied on to fill a pump full of water at every stroke, but it was known that a force often of many tons was required to discharge that water. If this force were properly controlled there would be no shock or empty return, but it should not be too suddenly or quickly applied, and there ought to be a pause or set.

Mr. WOODWORTH observed that the Hathorne-Davy arrangement was reckoned absolutely safe. However, no arrangement was yet made but it required some care and attention, and, if neglected, would cause accidents. The late Mr. Churm, of Bucknall, made a special valve for a pump that would only give a small supply of steam until the proper pressure was got in the pump, when a supply for full work was admitted; but it was not applied, as the pump worked efficiently without it. He also constructed a governor or controlling arrangement for a large pumping engine, which worked quite satisfactorily when the pump was fully loaded at one end and perfectly free from any load at the opposite end. This he (Mr. Woodworth) considered was a good test for any direct-acting pump.

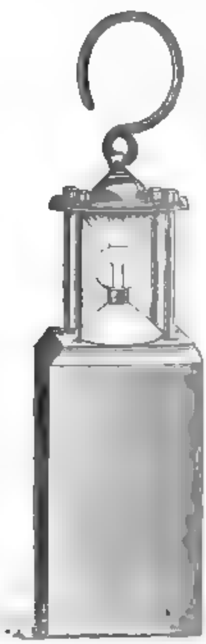
On the proposition of the PRESIDENT, a vote of thanks was accorded to Mr. Lockett.

Mr. V. C. DOUBLEDAY read the following paper on "The Sussmann Electric Lamp":—

THE SUSSMANN ELECTRIC LAMP.

By V. C. DOUBLEDAY.

The Sussmann electric miner's lamp differs in several most important points from all portable electric lamps hitherto produced; not only in shape and weight, but also in the battery, in which improvements are introduced affecting mining lamps and electrical storage generally.



The lamp measures about 2¾ inches square and 8 inches high, with a cubical capacity somewhat less than an average safety oil-lamp. The shape and design of the lamp are intended to utilize the whole of the light to the utmost advantage, especially by reflecting from the top and bottom that portion of the light which is usually absorbed by the lamp itself, and to be convenient for handling in any position. It is well protected against possible injury, simple in construction, and can, when necessary, be quickly taken to pieces, renewed, repaired, and put together again by any ordinary workman.

The weight of the lamp is 3 lbs. 11 ozs., being 8 ozs. more than that of an average safety oil-lamp, an altogether inappreciable difference. For the light given and duration of time it will burn, this is a great improvement upon any lamp of the same kind hitherto introduced. The electrical storage capacity of the battery is within a fraction of the theoretical limit; consequently, in point of weight and size, no further improvement can be looked for.

Taking the lamp without the advantages of the reflectors at top, bottom, and back, the amount of light produced (as shown by photometric tests) is 1 candle-power; but as the light at the top and bottom and of one-half of the circumference is reflected and concentrated on the working area, the actual available light much exceeds this. An object placed at a distance of 9 feet from this lamp is illuminated equally with

the same object placed at a distance of 5 feet from a newly cleaned and trimmed safety oil-lamp; and this represents nearly four times greater lighting-power. The greater penetration of the light is accounted for by the white actinic rays, as compared with the yellow flame of an oil-lamp. The white reflector at the back of the lamp was suggested by actual trials, although the light given without it was ample, as it was found that at a short distance from the workmen the brightness was a little dazzling after a time. The semi-transparent reflector not only cuts off the direct rays from the eye, but also concentrates and increases the light. The superiority of the light over that of oil-lamps when placed side by side underground is unmistakable, and the workmen state that after using an electric lamp for a short while, it takes a little time to get used to an oil-lamp afterwards, especially as the light is absolutely steady and free from the least flickering or variation. In common, of course, with all incandescent electric lamps, it requires no trimming or attention, so that time is saved in not having to take it to the lamp-station for that purpose. As an instance of the superiority of the light, in some pits where these lamps have been tried the managers have stated their intention when they obtain the lamps of discontinuing the payment of the extra price per ton which they now pay where safety-lamps are used instead of naked lights, as they consider this light to be better than a naked light.

After charging, the lamp will burn steadily for 16 hours, there being (to the eye) no perceptible difference in the amount of light at the end of that time from the amount of light at the commencement. Assuming that the average time a lamp would require to be burnt daily to be 9 hours, 16 hours would leave a large margin for emergencies. In cases of accidents, where workmen might be cut off from communication for a time, one lamp only should be kept burning, the others being extinguished and used one after the other as required.

This lamp possesses an advantage which gives it an undoubted superiority over every other electric lamp hitherto produced, viz., the fact that the battery contains no liquid acid, and on this point it stands alone. It is the only storage battery in existence which is practically dry, and which contains nothing to spill or leak out. Wherever liquid acid is used, and it is used in all other accumulators, it has the unavoidable result of attacking not only the connexions, but of entirely corroding or ruining the entire lamp, and even the case containing it, and this happens without exception. The result is that instead of a lamp lasting for years, it cannot even, under the most careful treatment, last for as many months.

It is unconvincing to merely state on estimate what the length of life

of this storage battery will be, although experts declare that it will far exceed that of the best forms of storage battery known; but it can, however, at a very modest estimate, be reckoned at five years. Owing to the battery being practically a dry one, the corroding troubles are avoided, and the lamp may be placed in any position, even upside down, and kept so if desired; and for the examination of roofs, awkward places, and on many other occasions, this feature of the lamp is a most valuable one, and will be fully appreciated by all having a knowledge of the various requirements of a miner's lamp.

The storage battery is barely 2¼ inches square and 5½ inches high, and between it and the outer steel case are buffers of elastic material, so that the outer case may receive bad usage without the battery itself being touched.

As to safety, no statement is necessary, further than that in common with all small incandescent electric lamps, it has been proved to be incapable, even when the glow lamp has been purposely broken in an explosive atmosphere, of igniting gas.

Mr. J. RICHARD HAINES enquired whether many of these lamps were being used?

Mr. DOUBLEDAY said there were not many in use at present. The first time the lamp was shown was three months ago in Yorkshire. The second time it was shown at Cardiff, so that it was absolutely a new invention, and had not yet been supplied for sale, although it was being tested at a good many collieries. It had been experimented with for some months.

Mr. H. R. MAKEPEACE—In the same form?

Mr. DOUBLEDAY—Substantially the same.

Mr. R. H. WYNNE said he understood that the lamp would burn 16 hours, and asked what time it required to charge it?

Mr. DOUBLEDAY replied that a lamp to burn 9 hours could be charged in 4 or 5 hours, but for one to burn a longer time (having regard to the life of the lamp) it would be better to extend the time to 8 hours. It could be charged quicker, but to do so would shorten the life of the lamp.

Mr. WYNNE asked if the glass-cylinder was as strong as that of an ordinary safety-lamp?

Mr. DOUBLEDAY answered that the glasses were supposed to be very strong. If the outer glass should be broken the inner one would be left, and even if the latter were broken the lamp would be absolutely safe.

Mr. WYNNE observed that in the Swan lamp, there was a lens in front.

Mr. DOUBLEDAY said that was not for strength, but for effect. He then stated that experiments had been made proving in numerous instances that the glasses had been broken in explosive mixtures and the lamp had not exploded the gas. Replying to Mr. Hassam, he (Mr. Doubleday) said after the lamp had been burning for 15 hours there was no diminution in the illumination. The lamp could be used in a wet shaft, or even in a bucket of water.

Mr. G. LAKE asked if it was possible to detect gas with this lamp?

Mr. DOUBLEDAY answered in the negative.

Mr. LAKE said, then you have to fall back on other inventions for detecting gas, but this lamp, with its capital light, would be very useful for examining shafts, roofs, etc., and at the working face.

The PRESIDENT said that defect applied to all electric lamps.

Mr. WYNNE said that Mr. Swan had been trying to invent such an addition to his lamp, but had not succeeded up to the present time.

Mr. DOUBLEDAY observed that after all the main object of the lamp was light. He said the lamp might be improved in little details, but as to its safety there could not be the slightest doubt. With a filament of the size used in this lamp it was impossible to explode gas, a fact which had been thoroughly proved by experiments.

Mr. R. H. WYNNE said he had heard some little doubt expressed lately as to the certainty of an electric lamp being safe. He had no doubt in his own mind that the filament was destroyed the moment that the inner globe was broken.

Mr. HASSAM asked if the lamp would break if dropped from a height of one yard?

Mr. DOUBLEDAY said lamps did get dropped occasionally, and neither the inner glass nor the filament of this lamp would be damaged.

Mr. WYNNE observed that the illuminating power of this lamp was equal to one sperm candle.

Mr. DOUBLEDAY said that was without the reflector; with the reflector it was greatly increased.

Mr. HASSAM referred to the protector lamp, which he said was an improvement upon any oil lamp he had seen.

Mr. HAINES—It is scarcely equal to this lamp.

Mr. HASSAM remarked that this was decidedly the best electric mining lamp he had seen.

Mr. DOUBLEDAY said the weight of the lamp might be reduced slightly if it was to burn a less time.

Mr. HAINES said in his opinion the lamp was a step in the right direction, as a portable lamp, and it gave a very good light. The advantages claimed certainly seemed to be obtained in this lamp. He moved a vote of thanks to Mr. Doubleday for his attendance.

Mr. WYNNE seconded the motion, remarking that the lamp appeared to be an improvement, with regard to portability, upon anything which he had seen before.

The motion was carried unanimously.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, OCTOBER 14TH, 1893.

MR. A. L. STEAVENSON, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on September 30th and that day. He also reported the proceedings of the Council of the Federated Institution of Mining Engineers.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. JOHN WATSON COOK, Colliery Manager Greenfield House, Crook.

Mr. LEWIS EVANS, Mining Engineer, Coetzeestroom Estate and Gold-mining Co., Limited, Kaapsche Hoop, North Dekaap, Transvaal.

Mr. FRANK SIMPSON FERENS, Mechanical and Electrical Engineer, 13, Railway Arches, Westgate Road, Newcastle upon-Tyne.

Mr. HENRY J. GIFFORD, Superintendent of the Ouro Preto Mines of Brazil, Limited, Mines de Passagem, Ouro Preto, Brazil.

Mr. FREDERICK HALL, Mines Manager, Harrington Road, Workington.

Mr. JOHN HEDLEY, Mining Engineer, Coatham, Redcar.

Mr. JOHN CARY BAKER HENDY, Mining Engineer, Etherley, by Darlington.

Mr. FRANK T. HOWES, Assistant Colliery Manager, Singareni Collieries, Hyderabad, Deccan, India.

Mr. WILLIAM HUMBLE, Government Inspector of Collieries, Coal-fields Office, Newcastle, New South Wales.

Mr. WILLIAM HAMILTON MERRITT, Mining Engineer and Metallurgist, 485, Huron Street, Toronto, Ontario, Canada.

Capt. G. NICHOLLS, H.M. Commissioner of Mines for Natal and Zululand, Pietermaritzburg, Natal.

Mr. RALPH NIXON, Lecturer on Mining to the Northumberland County Council, 47, Holly Avenue, Newcastle-upon-Tyne.

Mr. JOHN SHOTTON, Assistant Engineer, Locomotive Department, Ottoman Railway Co., Smyrna, Asia Minor.

Mr. JAMES JOSEPH TONKIN, Manager of Silver-lead Smelting Works, Linares, Provincia de Jaen, Spain.

ASSOCIATE MEMBERS—

Mr. HERMAN ALEXANDER KROHN, Secretary to the Roburite Explosives Co. Limited, 103, Cannon Street, London, E.C.

Mr. GEORGE FREDERICK MANSELL, Public Accountant, and Fellow of the Institute of Secretaries, St. Mary's Chambers, Church Street, Colchester, Essex.

ASSOCIATES—

Mr. JOHN THOMAS BOLAM, Overman, The View, Beamish, Chester-le-Street.

Mr. JOHN FAIRS, Under Manager, Escomb Bridge, Bishop Auckland.

STUDENT—

Mr. ALGERNON NOBLE, Mining Apprentice, Broomhill Colliery, Acklington.

The following gentlemen were nominated for election:—

MEMBERS—

Mr. FRANK J. AGABEG, General Manager, Apcar & Co.'s Collieries, Sitarampore, India.

Mr. J. A. CHALMERS, Mining Engineer, P.O. Box 357, Johannesburg, Transvaal.

Mr. J. CHATER, Mining Engineer, Bengal Nagpur Coal Co., Limited, Evelyn Lodge, Asansol, Bengal, India.

Mr. FRANCISCO M. COGHLAN, Engineer, Catorce S.L.P., Mexico.

Mr. F. LAWRENCE CORK, General Manager, Bengal Nagpur Coal Co., Limited, Barakur, Bengal, India.

Mr. THOMAS CROUDACE, Colliery Manager, West House, Haltwhistle.

Mr. JOHN ETHERINGTON, Consulting and Mechanical Engineer, 39A, King William Street, London, E.C.

Mr. CHARLES FERGIE, Mining Engineer, Drummond Colliery, Westville, Nova Scotia.

Mr. JAMES FLETCHER, Colliery Manager, Wickham and Bullock Island Collieries, Carrington, New South Wales.

Mr. EDWARD GLEDHILL, Engineer, Carolina Hacienda, Honda, Republic of Colombia, South America.

Mr. WILLIAM GRIFFITH, Manager, The De Beer's Prospecting Syndicates, Waterloo House, Aberystwyth, South Wales, and Fort Salisbury, Mashonaland, South Africa.

Mr. JOHN ERNEST HARDMAN, Mining and Consulting Engineer, P.O. Box 520, Halifax, Nova Scotia.

Mr. ROBERT GEORGE HIGBY, Mining Engineer, Manager, Borrea Coal Co., Limited, Sitarampore, Bengal, India.

Mr. ROBERT G. LECKIE, Manager, Londonderry Iron Co., Limited, Londonderry, Nova Scotia.

Mr. ALFRED BENJAMIN LINDOP, Mining Engineer, Blackball, *via* Greymouth, New Zealand.

Mr. GEORGE HAMILTON LLOYD, Civil and Mining Engineer, Dolgerddon Rhayader, Radnorshire.

Mr. CARR WALLER PRITCHETT, Jun., Mining Engineer, Apartado 84, Pachuca Estado Hidalgo, Mexico.

Mr. C. ROBINSON, Engineer, c/o Messrs. Wilmard, Spillhouse, & Co., Cape Town, South Africa.

Mr. ALFRED F. SEECOMBE, Mining Engineer, Albaston, Gunnislake, Cornwall.

Mr. CHARLES WILLIAM SIBOLD, Civil Engineer, Public Works Department, Bengal Civil Service, Mirzapore, N.W.P., India.

Mr. PEREGRINE OLIVER WILSON, Mining Engineer, 30, Finsbury Circus, London, E.C.

ASSOCIATE MEMBER—

Mr. HENRY DAVIES, Lecturer in Geology and Mining for the County of Glamorgan, Treharris, R.S.O., South Wales.

ASSOCIATE—

Mr. RALPH B. DORMAND, Under Manager, Waldridge Colliery, Chester-le-Street.

STUDENTS—

Mr. WARDLE ASQUITH SWALLOW, Mining Student, Bushblades House, Lintz Green.

Mr. THOMAS JAMES TOMLINSON, Student, Harton Colliery, South Shields.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, NOTTINGHAM, 1893.

The report of the proceedings of the Corresponding Societies Committee of the British Association was read, and of Prof. J. H. Merivale, the delegate of the Institute, as follows:—

NEWCASTLE-UPON-TYNE,
SEPTEMBER 25TH, 1893.

TO THE PRESIDENT AND COUNCIL OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

DEAR SIRS,

The delegates from the Corresponding Societies met at Nottingham on the 14th and 19th inst. I attended both meetings.

The Chairman, Dr. J. G. Garson, drew attention to the advantages that are enjoyed by the societies corresponding with the British Association. Among these I may mention one which is not perhaps realized by many members of the Institute, viz., a classified list of all the papers published each year in the *Transactions* of the Corresponding Societies is printed in the Annual Report of the British Association.* This list or index fills no less than 96 pages in the Report for last year, and is

* This list is reprinted annually in the *Transactions of the Federated Institution of Mining Engineers.*

obviously of great value to all students. The *Transactions* of the societies are placed upon the shelves of the library of the British Association, where they can be consulted by the members of the Corresponding Societies.

The Earth Tremors Committee wish to make experiments in a mine, and as this is a subject in which the members of the Institute are interested, it might be advisable to purchase one of Prof. Darwin's pendulum seismographs and set it up below ground at a colliery in this district.

With reference to flameless explosives, I reported that the experiments of the committee of the North of England Institute were progressing, but had not yet reached a stage when a report could be published. Prof. H. B. Dixon asked—though not at the delegates' meeting—if we had tried ammonium nitrate cartridges, and advised our doing so.

The Underground Waters Committee hope to present their final report next year; meanwhile, they will be glad of information, which may be sent to Mr. C. E. De Rance, 28, Jermyn Street, London.

The Committee on Erratic Blocks (Secretary, Mr. P. Kendall, Yorkshire College, Leeds) want information from Durham and Northumberland.

Information too is asked upon the denudation of high-lying drainage areas by Mr. W. Watts, Oldham Corporation Water Works, Piethorn, Rochdale.

A morning in the Chemical Section was devoted to the question of explosions in mines, with especial reference to coal-dust. Messrs. Clowes, Dixon, Galloway, Hall, Lupton, Thorpe, myself, and others took part in the discussion.

Yours faithfully,

JOHN H. MERIVALE.

The PRESIDENT read his inaugural address as follows :—

PRESIDENTIAL ADDRESS.

BY MR. A. L. STEAVENSON.

On taking my seat as President of this Institute for the first time, it recalls my earliest recollections of its meetings, its members, and its general surroundings in the old building, then known as the Neville Hall, which stood back about 50 yards from the front street, a two-storied stone structure, black with the smoke of centuries. It had been built by the Baron of Bywell and Bolbeck, and hence had been called Bolbeck Hall; but when its founder in 1378 was created Earl Marshal, it received the name of Westmoreland Place.

It does not seem clear whether that which I remember was the whole of the original building, or whether the Literary and Philosophical Society, in building their library, had already destroyed a portion of it; but after travelling up and around its newel staircase of stone steps, on the afternoon of one of the meeting days, we reached a long low room, almost filled by a table, around which the members sat on cushioned benches.

And there would generally be found in the chair our first President, Mr. Nicholas Wood; on his right Mr. Tom John Taylor, on his left Mr. Doubleday, our first Secretary, and amongst others present Mr. Matthias Dunn, Mr. Barkas, Mr. Edward Potter, Mr. T. Y. Hall, Mr. J. J. Atkinson, Mr. Wales, Mr. J. Easton, Mr. E. F. Boyd, Mr. William Anderson, Mr. Chas. Carr, Mr. T. E. Forster, Mr. J. Marley, Mr. T. G. Hurst, Mr. James Willis, Mr. R. S. Johnson, Mr. W. Southern, and Mr. James Morrison, who have now all left us; but the active part they took in those early days entitles them to be remembered, and it is pleasant to do so. "I am forgotten as a dead man out of mind" is I fear the lot of most of us, but to-day we will make an exception to the rule.

Now, we were exceedingly fortunate in our first President: in Mr. Doubleday's memoir of him, he says:—"At Killingworth colliery, the young man was thrown into the society of one who exercised a considerable influence over his future life; and whose own arduous and successful career his young companion unquestionably assisted to bring to a fortunate issue. This was George Stephenson—then himself a young man—whose persevering ingenuity had already begun to attract attention, and who about

this time was made directing engineer of Killingworth High Pit. In young Nicholas Wood, Stephenson found exactly the coadjutor he wanted. He found his companion endowed with imperturbable good temper, a docile disposition, great power of application, and perseverance under difficulties hardly inferior to his own. Young Wood became accordingly the confidant of Stephenson; the depositary of his plans and schemes of whatever description; and his assistant in that series of persevering experiments which at last resulted in the modern locomotive, which, but for the early and irrepressible energy of Stephenson and his young companion, might yet possibly have remained a desideratum."*

But not only was Mr. Wood the friend and assistant of Mr. George Stephenson during the development of the locomotive, he was also the author, in 1825, of the first work upon railroads, a work now of the greatest historical interest, and filled from one end to the other with valuable experiments upon all kinds of subjects connected with railways. Take for instance page 197 of the second edition, published in 1830, a copy of which he presented to my father, and which for more than forty years has had a place on my bookshelves. He says—"Impressed with the importance of knowing the precise amount of resistance opposed to the motion of carriages along railroads, and also the resistance by different forms of carriages, Mr. George Stephenson and myself, in October, 1818, commenced a series of experiments upon the Killingworth railroad to ascertain that desideratum."

Then we have a lengthy account of experiments upon horse work—upon the strength and deflection of cast and malleable iron rails, others on the friction of ropes on various engine-planes, others on locomotive work, and in fact a treatise, which at the time it was published, was of national importance.

With Mr. Wood as chairman thirty-seven years ago, my own part in the proceedings of this Institute was limited to that of an attentive listener, but within less than three years I was busy with my first paper on "The Manufacture of Coke,"† and from that time to the present I have endeavoured as far as possible to promote the objects aimed at by its founders.

That those efforts have not altogether been unsuccessful, I am proud to recognize in your selection of me to fill this office.

With a view of avoiding repetition and obtaining a proper grasp of the situation, I have again read over the addresses of all my predecessors

* *Trans. N. E. Inst.*, vol. xv., page 49.

† *Ibid.*, vol. viii., page 109.

We have seen how Mr. Wood and Mr. George Stephenson, in the early days of the railway system, having no data to guide them, set to work to ascertain facts for themselves.

Such work is valuable, not merely in itself, but in the experience it affords, and the training it supplies to the experimentalists. What dissection is to the doctor, the practical test is to the engineer, and what he has proved by his own labours day by day, becomes in time the experience, which assists him at every turn, and invests his opinion with all its value.

To the mining engineer especially, in every department of his work, from the boiler on the surface (which supplies his power) to the face of his mine, every part of his machinery, every apparatus of whatever kind, and every material which he uses, should at some time have been tested, and its value accurately ascertained.

An examination of our *Transactions* will show that they largely consist of records of such work, and in that their chief value consists. But while they supply us with information of what has been done by others, they by no means obviate the necessity of proving all things ourselves.

In this work, in the course of my now somewhat long experience, nothing has struck me more forcibly than the difficulty, but necessity, of getting accustomed to exercise strict accuracy: nothing is more common than to find results obtained by experiment diametrically opposed to each other, and facts alleged to have been ascertained absolutely incompatible with known possibilities. Some one, perhaps, has invented a particular mode of firing boilers; he immediately, without any experience in such work, sets about proving that the use of his method results in a saving of 25 per cent. of fuel. Or he puts down a new pumping arrangement, tests it, and claims to be doing 20 per cent. more work than by any other system.

It ought to have been obvious to the man who tested the boiler fires that no form of firebar would alter the quantity of heat given off by a pound of coal, and that the only possible advantage to be gained was in the saving of manual labour, always assuming that the heated gases have been properly supplied with atmospheric air, and not allowed to pass to the chimney until that heat has been exhausted by contact with the boiler.

In like manner, the boiler itself has been subject to perhaps more careless experimenting than any other apparatus. A very large proportion of results so obtained have been found absolutely useless. The tests of a few hours, which are commonly made with the water marked on the gauge, and the fires judged by appearance at the beginning and end of the time,

have little, if any, value, the duration of the experiment having been far too short: such tests should never extend over less than a week, and a month's test would be much more worthy of credit.

Of ventilating fans in the last thirty years there has been no end, and as each new one appeared it was said to have excelled all previous efforts; until, as we have seen, the work done, according to the statement of the persons who tested them, has exceeded the power applied. And the question which arose was, not as to the accuracy of experiments, but to prove how such a result was possible. Let us discuss this inaccurate work in respect to fans a little further.

A powerful machine is newly erected, and after a few weeks' running the manager of the colliery, who is anxious to realize the benefits he has anticipated, the manufacturer of the machinery, who has his interests also at stake, and probably the patentee of the fan, no less wishful to obtain a good result, meet on a certain day to go through the ordinary operations involved in such an experiment. The speed of the fan and the engine must be taken, the water-gauge has to be observed, and the air measured. In all these apparently simple details, and without the slightest intention of dishonesty, it is no uncommon thing to get results 20 per cent. more in favour of the machine than it really yields.

The fan is probably 40 or 45 feet in diameter; and an error to the extent of one single revolution per minute would reduce, to a very appreciable extent, the true horse-power exerted by the engine. The water-gauge may have been placed in a position where it will show 10 or 15 per cent. greater vacuum than it is really putting upon the pit, and the reading of it accurately is also a source of much error; in fact, three persons looking at it and reading it at the same time will very frequently, if they make a note of their observations without communicating to each other what they have got, find their readings differ by as much as one-tenth of an inch. But it is in the accurate measurement of the air where the most fallacious results have been got. The influence of currents at the top and bottom of the drifts, and the irregular flow of air where there are any bends near the point of measurement, make the work one of much more difficulty than is commonly believed. That any man who can hold an anemometer and read it is capable of measuring an air-current without wide experience or thorough instruction is a fallacy of the most serious character. Only in a drift which is fairly straight and of a sufficient length to allow of the point of measurement being at least 20 feet from any cross drift or sharp bend, and divided by strings into equal areas, and by allowing the anemometer to remain in each space, say 30 seconds, can accurate results be obtained.

Now, when we consider all these delicate operations in the hands of such observers as I have already alluded to, and the interest which all conducting the trial have in obtaining a good result, it is easy to understand how these errors are propagated.

But when once the fact that the work is not simple, but demands the strictest care has been grasped, one half of the difficulty has been overcome; and it is in the training and experience which such experimental work affords that a large share of the amount of advantage consists which is gained by the engineer.

It is, perhaps, not necessary to follow this subject further; but the same lesson which is inculcated by the testing of a fan is taught in whatever department he is engaged.

It is obvious that these remarks naturally lead us to consider how the engineer can be best fitted to perform these duties, and, in fact, how he should be educated.

We have seen within the last twenty-five years a College of Physical Science founded in this city, which will, I trust, go far to remedy the rule of thumb which has prevailed so much in the performance of work such as has been described. In speaking of this valuable institution, I wish, at the earliest moment, to express my heartiest recognition of the good work done personally by its professors in the assistance they have at all times given to this kindred society. I cannot make any distinction amongst them, although I am sure I speak nothing more than the universal feeling of the mining and mechanical engineers when I express my very great regret that we are about to lose from amongst us Professor Garnett.

But the college alone will not suffice, and I will, therefore, venture to describe what the experience of more than forty years has led me to consider as the most suitable training.

Assuming that a youth has been well educated, and reached the age of sixteen years, he will be able to read and write his own language correctly, he will have obtained the rudiments of French and German, and as much Latin as will enable him to read Virgil or Cicero, together with mathematics, so far as, say, simple algebra. At this time the sooner he gets a couple of years of thoroughly good pit experience the better, and nothing will obviate the necessity of a master to show him what work he ought to do, and to see that he does it.

No college will ever supply the experience so obtained. Moreover, the position he will hold in life involves such questions as the value of work and the cost of production, he must have acquaintance with such matters as the measurement of work, of the letting of bargains, of pit bills, and

the management of men, surveying and the keeping of plans, and the practical questions which arise in the ventilation of the pit. None of these things can be gained at college, but after two years of pit work he should have a couple of years there, and he will realize the advantage which his pit work has given him in the knowledge of what the information is he requires; he will be able to understand the value of the subjects he is studying, and having in this way reached the age of twenty, another good year of pit work will find him at twenty-one thoroughly accomplished, and wanting that experience which time can alone supply.

He will, however, have first to pass the examination and obtain his certificate, and if what is called his leisure time has been well spent, this he will easily do. Having myself, since 1872, when the Act requiring these examinations was first passed, acted as one of the examiners for the South Durham, Cleveland, and Westmoreland districts, I feel entitled to say a few words on the subject.

The greatest benefit which these examinations have conferred has been of an indirect character, for, whereas previously a young man gained the practice afforded by his pit work, only in a few cases was it accompanied by that theoretical knowledge which is to be obtained from books. The pit shift being over in the morning, with perhaps a survey plotted in the afternoon, the newspaper or the pipe filled up his remaining time; but with an examination to face, such subjects as geology, chemistry, and mechanics have to be thought about and studied, and when once the rudiments are acquired, in many cases a taste is awakened for information about which he otherwise would have known nothing. That which began in the nature of a school lesson becomes an absorbing recreation for perhaps a lifetime.

Let it, however, not be supposed that, in speaking as I did a short time since of rule of thumb, I deprecate in any degree self-taught knowledge, as the following will illustrate. Thirty years ago we had no college to assist us, and after ten years in the colliery district, where I had done perhaps more than the ordinary share of surveying which falls to the lot of a young man, I took charge of some mines in Cleveland. There, with new plans to make, it was soon evident that the ordinary miner's circumferentor would not suffice; I could not read the theodolite, and had not the least knowledge of the bookkeeping or calculations it involved. But having procured an instrument, without accepting the assistance of any of the works of instruction upon the subject, and being able only to calculate the sine and cosine of an angle, I made out a method of doing the work, so that in two or three weeks I had made a survey of

more than 4 miles from start to finish and over some of the roughest ground in Cleveland, and I was able to tell by calculation that there was an error of 7 links in the survey.

I might, perhaps, have been taught at a college in lessons of a few days that which took me as many weeks to discover for myself, but the satisfaction and pleasure experienced as each feature of the investigation revealed itself well repaid the labour spent in personally acquiring the information.

Before leaving this subject, I will say a few words upon the technical education of Continental engineers as compared with our own. It has been very often said that we were being left behind by our brethren on the Continent. Now, I have had many opportunities of meeting with French and Belgian engineers under circumstances which permitted me to form a fairly just opinion of their qualifications. I have read their mining literature, translated and published some of their works, and I have certainly failed to find them, when taking them all-round, as we say, superior to ourselves in their capacity for the ordinary, everyday work of colliery management.

I am inclined to say that, whilst the English colliery viewer of forty years ago had good practical skill alone, and the Continental engineer to-day excels somewhat in theoretical attainments, we have here that happy blending of science and practice which renders the Englishman, although by no means perfect, the best man of the two.

I will now briefly refer to the work which lies before us. We have seen during late years powerful trades unions established in all classes of labour. I am by no means prepared to say that their influence has been upon the whole injurious; for they have to a considerable extent introduced order where there was before chaos. Arbitrations, joint committees, and the leaders of the workmen in this district at all events give us something tangible to work with, but nevertheless as these organizations become more powerful and less labour can be bought for the same wage, it devolves upon the engineer to invent such mechanical aids as will enable him to reduce the amount of manual labour he requires, and work his mine without increased cost.

Still more important is the work which this Institute was especially founded to promote, viz., that of the safety of workmen. The inspector of mines for the Durham district has more than once brought under our notice that falls from roof and sides produce more than one half of the accidents. In his report for the year 1890, after quoting the special rules upon the subject, he says, "Yet in face of these stringent regulations, no

less than 56·75 per cent. of the whole of the deaths in the district took place from falls during the past year, many of them I regret to say from sheer carelessness and disobedience to orders."

They are a class of accidents very difficult to prevent. I have seldom made an underground examination during which I have not had to caution workmen that they were then incurring danger, and insist upon precautions being taken; all that can be done is to caution and educate the workmen, and punish all who break the rules which are instituted for their protection.

The class of accident which ranks next in importance are those known as "miscellaneous underground," and which in 1891 were 24 per cent. of the whole, those in shafts 12 per cent., on the surface 10 per cent., and for explosions 5¼ per cent.

Upon the manager rests the responsibility of leaving no means untried for improving his own experience, and perhaps in no way can this object be better attained than by a constant attendance at the meetings of this Institute, where every novelty and improvement in the art of mining is brought before us and discussed.

We may, however, point to the statistics of accidents which have occurred since the founding of this Institute with much satisfaction, for we find that, at that time, the ratio of persons employed to each death was 233 to 1, whereas in the last four years, which include 1891, the deaths averaged 580 to 1, or just 2½ times the number of persons employed per fatal accident, an improvement for which we may fairly lay claim to a considerable portion of the credit; the averages for Durham and Northumberland being 895 persons per life lost.

No subject has been more constantly brought before us of late years than that of the value of electricity for lighting and transmission of power, and after what may be termed a youth of wild extravagance it is now, I hope, settling down to a maturity of reasonable and quiet usefulness. Its value and its drawbacks are being proved and admitted.

So far as its lighting value is concerned, it is doubtful whether it has much use for the mining engineer; as the quantity of light he requires for surface operations is comparatively small. But if what may be termed fire risks can be efficiently overcome, it will prove valuable where a good light is required in the screening and cleaning of coals. Many attempts have been made to produce a portable miner's lamp. For my own part I am so thoroughly satisfied with the safety of the lamps we now use, that I have not taken much interest in the attempts to solve the electrical difficulty. Before leaving the subject I should like to emphasize what I

have said upon this question on former occasions, and which I know has been often misunderstood. It was to the exaggerated and utterly misleading statements as to the efficiency of work done by electricity, which were for a long time promulgated, that I objected, such statements being based solely upon the the difference of power put into the dynamo by the belt, and measured in electrical efficiency at the motor.

Now, the cases are very, very few in which it is possible to utilize that power in the motor directly. In, say, a pump intermediate gearing must be used on account of the speed of the motor, causing much loss, and hence results of experiments most recently brought before us have entirely confirmed the views which I had expressed, and which must be obvious to any impartial observer, but more particularly was I annoyed by these electrical efficiencies being placed in comparison with results got where water actually lifted had been compared with the work done by the steam in the cylinder. I am able to quote if necessary scores of these cases in which electricity is said to give 65 to 75 per cent., whilst compressed air gave 30 per cent. But as has been well said, "Magna est veritas et prevalebit." For the transmission of power over distances exceeding 1,000 yards it has proved itself a valuable helpmate, although the first cost of electrical plant will, I hope, be capable of reduction; whether it is a suitable medium to take into a mine beyond the lamp-station or caution-board those who adopt it must decide for themselves.

The coal-dust question has agitated the minds of all connected with collieries in the last few years, and there are some I believe who still shake their heads and refuse to admit the possibility of any of our great explosions having originated through dust alone. The matter seems so clear to me that I have taken very little interest in the later discussions on the subject. There is and can be no dispute of very serious explosions having occurred repeatedly where no gas could possibly have been present. I will mention a few cases just to confirm my statement. In 1886, an explosion occurred in flour mills at Leith, when three persons were killed and four injured. In 1882, an explosion occurred in a flour mill at Macclesfield; a large part of the mill was levelled with the ground, and damage to the extent of £5,000 was done, the engineman being killed. In 1887, an explosion occurred in the United States in some wood-working establishments at a point where the dust and shavings were gathered together: the roof of the shaving-house was blown off and two of the workmen killed. In 1885, an explosion took place in a rag mill at Drighlington, causing the death of two workmen. This was an explosion of the dust at what was described as "the shaker."

There was no possible gas present in these cases, and when we remember that explosion is only a rapid form of combustion to which the fineness of the particles of dust make it peculiarly susceptible, and that coal-dust if heated contains 10,000 cubic feet of gas to the ton, it is difficult to conceive how anyone can still harbour a doubt on the subject. The case seems analogous to that of those who, for many years, whenever a boiler explosion took place, insisted that there was something about boilers we did not yet understand, and it was often asserted that electricity had something to do with it. To such we can only extend our sympathy.

We have lived at a period when events have marched rapidly. In our Vice-President (Mr. Wm. Armstrong) we have the champion of the battle of iron *versus* hemp ropes: a strike of thirteen weeks was required at the Wingate Grange colliery in 1843 to convince the workmen that iron ropes were safe, and at its conclusion the coalowners, fitters, and agents gave him a dinner at Durham in recognition of his victory. I trust he will some day give us an account of the state of coal-mining in his early days, when candles, 60 to a lb., held the place of the safety-lamp of to-day, when coal was brought to bank in corves, and haystack boilers supplied the steam. Such reminiscences are not merely interesting, but often prove useful. There was a case in the law-courts a short time ago in which the question of when the mode of working out all the coal instead of leaving small pillars was first practised, and no precise evidence could be found. So we never know how incidents, which are now common knowledge, may some day prove important, when all record of them has been lost. Let us seek to make the *Transactions* a storehouse to which future generations can always refer, and which will serve to hand down our names and the work we have done to those who come after us.

In conclusion, I would urge strongly upon all, whether owners or engineers, the duty of assisting this Institute in every way; let the former recognize that in the efficiency of his agent (which it promotes) his deepest interests are involved, and the latter see that the profession he has adopted is raised and honoured by the world at large, in proportion as it takes its place amongst societies distinguished for the science and learning of their members.

Mr. G. B. FORSTER said he was sure the members would all join with him in according to their new President a most hearty vote of thanks for his inaugural address. Mr. Steavenson had commenced with their early years and their first President, and taken them through the various

points which had attracted his notice as being for the good of the coal trade and for the scientific advantage of the Institute. Young men in particular would profit considerably by laying to heart what the President had said about accuracy of observation and deduction. They must join with the President in the hope that the Institute would continue to prosper and be of use to the members generally.

Mr. M. W. Parrington hoped he might be allowed, as the President's senior pupil, to second the vote of thanks. He could bear out what had been said as to the value of education for mining students. When he went to serve his time with Mr. Steavenson twenty-nine years ago he had not the advantages which were now afforded by Colleges of Science, although he must at the same time admit there was not the same competition. Competition no doubt was a very healthy thing, and would lead to greater efforts on the part of mining students at the present day.

Mr. Emerson Bainbridge said that, as an old friend of the President, he had come that day to have the pleasure of listening to his address, with which he was sure they must all be gratified. It was well known that of all their members no one had been more an exponent of accuracy than Mr. Steavenson himself, and he might venture to define the President's chief characteristic to be a determination to prove the accuracy of his conclusions, although this resolve might sometimes result in the destruction of some pet theories, causing him to change his views. He thought on the question of general education, that it was desirable to develop more and more instruction in mechanical engineering rather than to overdo the pit-work. If out of a five years' tuition two years were devoted chiefly to pit-work and three years devoted to mechanical engineering, he thought such a division of time would tend to make better colliery managers than had been produced in the past. This was shown in the training of the French mining engineer, who, though he might not have an equal knowledge in the practical management of a colliery, could lay out the complete plans of a large colliery plant, being better able to deal with questions of mechanical construction than was generally the case in England.

The vote of thanks was carried with acclamation.

The President, in acknowledging the vote of thanks, said that he had had considerable difficulty in making up his mind to accept the position of president on account of the deafness with which they all knew he was afflicted, and which made it difficult to hold such an office. Relying, however, on the kind assistance of his friends he could not forego the honour, and he would be glad if at the end of his term he should find that the Institute had not suffered by his holding the office.

DISCUSSION ON MR. V. C. DOUBLEDAY'S PAPER ON "THE SUSSMANN ELECTRIC LAMP."

Mr. V. C. DOUBLEDAY exhibited and described the Sussmann Miner's Electric lamp.*

The PRESIDENT said the Sussmann lamp appeared to be a very good form of electric lamp, but it had the defect of being without an attachment for indicating the presence of gas.

Mr. J. L. HEDLEY (H.M. Inspector of Mines) said they all knew that under certain conditions and so long as the incandescent filament was excluded from the atmosphere an electric lamp was safe, and no doubt if the use of such lamps were considered advisable they would look out for the best one. The point raised by the President was a very important one, and for his own part he thought a great risk would be incurred by introducing such lamps unless provided with some means of ascertaining the state of the atmosphere in the mine.

Mr. DOUBLEDAY said that the lamp as now constructed did not indicate the presence of gas.

Mr. W. O. WOOD said he had had some experience with electric lamps, and the rincipal difficulty he thought connected with their use was with regard to the charging. He presumed that a dynamo would be required for the purpose of charging and recharging the lamps. There was also a difficulty in ascertaining whether a secondary battery was properly charged or not; sometimes a lamp had been issued partially charged, with awkward consequences to the user. He thought that the glass-cylinder of the electric lamp would probably be of the same strength as any of the glass lamps ordinarily in use, and even if the outer glass were broken there was still the protection of the glow-lamp globe inside. The use of a means of indicating the presence of gas was perhaps hardly necessary for general use by the ordinary workmen, inasmuch as there were so many examinations now made by deputies and other officials who could be supplied with an apparatus to ascertain whether the places were safe or not. In the case of a sudden outburst of gas there would still be little risk, but the deputy would discover it on his return visit.

Mr. J. L. HEDLEY could only partially agree with Mr. Wood's remarks. If the deputy happened to be present when the outburst of gas occurred he would, of course, warn the workmen; but taking into consideration the long intervals that frequently occurred between his visits, he thought it important that all lamps should indicate the presence of gas (either

* *Trans. Fed. Inst.*, vol. vi., page 264.

fire-damp or stythe), and show the workmen the state of the atmosphere. He did not want to say a word against the electric light, for he thought it was an improvement, in many respects, on the type of lamp now in use, but it would be a great mistake, he thought, to use a lamp that might lead to something, perhaps not worse than had more than once occurred, in case of an inrush of gas, but to more serious consequences in what may be called the ordinary working conditions of the mine.

Mr. W. C. Blackett said he was in the habit of carrying an electric lamp, and could corroborate Mr. Hedley's warning. The increased light was a great convenience, but he never felt very safe in going about alone with it. He had to travel in both fiery and stythy mines, and he did not care to go into either unless he was accompanied by a man with an ordinary lamp. He quite agreed that it would be unsafe to leave a man alone with an electric lamp in a stythy mine—less safe than in a fiery mine—for many hours.

Mr. J. C. B. Hendy agreed with the previous speakers as to the inadvisability of adopting such a lamp generally without any means of testing for the presence of gases. Some time ago he had headings going through a large fault and a considerable length of disturbed ground, and although there was a strong air-current they had found much gas previously. He would certainly not have placed electric lamps in the hands of the workmen in those headings unless they had been fitted with some means of showing whether gases were present. He did not think it would be wise (as Mr. Wood suggested) to trust to the deputy's periodical visit with a safety-lamp, as within half an hour or less there might be a sudden outburst of gas with serious consequences. At the same time he thought, apart from gas-testing, that electric lamps were a step in the right direction.

Mr. C. J. Murton suggested that the difficulty might be overcome by attaching to the electric lamp, or fixing into a recess, a miniature oil-lamp of the ordinary shielded gauze type, and with a correspondingly small wick and flame. Such an addition would only add a few ounces to the weight of the lamp, and the presence of either fire-damp or stythe would be made apparent in the usual way.

Mr. G. B. Forster noticed that the weight of the electric lamp was 3 lbs. 11 ozs., or about 7 ounces heavier than the ordinary Marsaut lamp. In the case of the workmen the additional weight of the lamp was not very material, as they did not carry them for a long time. A heavy lamp was, however, a drawback so far as the manager of the mine was concerned. He thought this lamp was better than others in which a lens

was placed in front, and consequently only threw the light on one point, leaving the remainder of the space in darkness. There were two points into which discussion might be divided: first, that of safety; and secondly, the question of an efficient light. With regard to safety, he thought the glass in this lamp was not (as Mr. Wood had said) quite as thick as a Marsaut lamp glass, although in this respect it could be improved; but the greatest objection on the score of safety was no doubt that which had been referred to—the lack of some means of detecting the presence of fire-damp or stythe; and until some such means were provided he did not think it would be expedient to introduce the lamp into their mines, although no doubt the light given was a very good one.

Mr. J. A. Ramsay asked if any observations of pit-gases had been made through a prism with the view of obtaining the qualitative composition of the atmosphere seen through, or if a spectral analysis could not be obtained by an application of prisms to decompose the beam of light from the lamp?

Mr. M. Walton Brown enquired as to the length of time required to recharge the batteries? He understood that a secondary battery required considerably more time to recharge than the lamp would burn when charged; and, as a consequence, in the case of lamps burning more than ten hours per day, a double set of lamps would be required, so that one set could be recharged while the others were in use. There was a difficulty in the application of indicators of the presence of gases, as the electricity used to work a Maurice, Liveing, or Swan fire-damp indicator was much greater than that required to heat the glow-lamp filament, with the result that the battery of any electric lamp would be run down in about half an hour if used continuously for gas-testing. These fire-damp indicators were of no use in testing for stythe, and some other appliance must be used for its discovery.

Mr. Doubleday said that assuming a lamp was used for nine hours in a mine, it could very safely be recharged in eight hours, but having in view the length of life of the battery, the more slowly they were charged the longer the life of the lamp.

The President then proposed a vote of thanks to Mr. Doubleday. They were pleased to see the lamp, which appeared to be an improvement on others which they had seen, but whether it would be more enduring or not, time alone would show.

Mr. G. B. Forster seconded the vote of thanks, which was adopted.

DISCUSSION ON MR. LEACH'S PAPER UPON A "CORLISS-ENGINED FAN AT SEGHILL COLLIERY."*

Mr. J. C. B. Hendy said that the paper was very interesting, and it showed that while attention had been given to manometric efficiencies and volumes, the important matter of the efficiency of the entire plant had been somewhat neglected. In the experiments he (Mr. Hendy) had made at Teversal collieries† the amount of coal and water used was recorded, and he noticed in the discussion which followed the reading of Mr. Leach's paper that the amount of water or steam used at Seghill collieries was compared with the amount used at the Teversal colliery, showing that a saving of over 75 per cent. had been effected at Seghill. There was a great difference between the conditions at the two collieries. He thought that the chief source of saving was due to the feed-water being heated by the exhaust steam. Teversal was an old colliery and it would have been difficult to have applied such an arrangement. At Teversal, the feed-water had a temperature of only 60 degs. Fahr., while at Seghill it was stated to be 115 and 172 degs. It would be interesting if Mr. Leach could state the saving between using water heated to 172 degs. and at the ordinary temperature of say 60 degs. He (Mr. Hendy) thought that the coal used (and not the water entirely) was the measure of the efficiency of the engine and boiler, and it was as important to look to the boiler as to the engine.

Mr. C. C. Leach pointed out that he purposely omitted from his paper the amount of coal used, and the weight of coal burnt was only mentioned in the discussion. It was not fair to charge the engine with the difference which might result from the use of bad coal as compared with good coal and of one boiler with another. The heat in the steam used at Seghill colliery was 1,300 degs., and as the difference of temperature of the feed-water was only about 90 degs., the consumption of coal would only have been one-fifteenth more, if the feed-water had been used at a temperature of 60 degs. instead of 150 degs. The loss would have been very small, say ¼ lb. of coal per indicated horse-power. He might add that the temperature of the feed-water did not affect the weight of steam used per indicated horse-power.

Mr. Hendy said he thought that the Seghill engine was the most economical one used for driving a fan that he had heard of.

Mr. Leach said the economy of the engine was obtained by getting the full pressure of steam on the piston at all speeds, automatic and

* *Trans. Fed. Inst.*, vol. vi., page 48. † *Ibid.*, vol. iv., page 474.

instantaneous cut-off, and the short length of the ports. It was thought undesirable to erect a compound condensing engine for the power required, more especially as the builders guaranteed an economy which other makers said could only be obtained from a compound condensing engine.

The PRESIDENT said that no further remarks being offered the discussion would now be closed.

DISCUSSION ON MR. EDWARD HALSE'S "NOTE ON THE OCCURRENCE OF MERCURY AT QUINDIÚ, TOLIMA, U.S. COLOMBIA."*

Mr. ARTHUR L. COLLINS (London) wrote that in addition to the useful list of cinnabar deposits, contained in Mr. Halse's paper, that there were two other occurrences which had come under his notice. At Zalathna, in Transylvania, small veins and impregnations of cinnabar have been very extensively worked in sandstone. The richer parts were worked as poor men's mines, leaving large quantities of low-grade stuff which would require more elaborate plant for treatment. At Kilkivan, near Gympie, in Queensland, more or less cinnabar has been found over a very large area, and when he (Mr. Collins) was there in 1890 he found some pounds weight of rolled pebbles of pure cinnabar (from a pea up to a large walnut in size), by panning in a small gully cut by the rains in the subsoil. The country rock is conglomerate, of Carboniferous age, lying nearly horizontal, consisting of pebbles and fragments of quartz porphyry and other volcanic rocks, with a crumbling ferruginous cement. It is pierced in places by dykes of diorite, and by many large vertical fissure veins of dolomite and calcite, often brecciated. The veins (one of which has been worked to depth of 200 feet) are often quite free from metallic minerals; but sometimes they show brown hæmatite, blue and green carbonates of copper, and cinnabar in patches, or as stains in chalcedony and calcite. In one vein a mercurial fahlerz is also found, in quantities sufficient to be used as an ore of mercury. The ore, as raised, is mostly very poor, and would require the erection of a large furnace for its treatment. No vein has as yet been followed down through the conglomerate, which is of unknown thickness.

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* *Trans. Fed. Inst.*, vol. vi., page 59.

DISCUSSION ON MR. E. S. WIGHT'S PAPER ON "QUEENSLAND COAL-MINING; AND THE METHOD ADOPTED TO OVERCOME AN UNDERGROUND FIRE."*

Mr. T. E. FORSTER said that Mr. Wight's paper was interesting, from the fact that it contained a record of the early days of a coal-field, which may some day be of considerable importance. The Ipswich coals seem to be worked under very similar conditions to those of the Barrum river, which he had visited in 1887. The quality of the Queensland coals is generally considered to be inferior to that of the New South Wales and New Zealand coals, but it was quite possible that further development might bring improved quality. At present the limited market was naturally a great bar to any rapid increase in the output. Underground fires had, he believed, given a good deal of trouble, and were generally caused by the small coal left in the workings. Mr. Wight stated that the natural heat of the mines was great, and it would no doubt be interesting to have some particulars of underground temperatures taken in these collieries. Mr. Wm. Fryar, inspector of mines for the southern division of Queensland, took some observations a few years ago in various gold-mines at Gympie, about 100 miles or so north of Ipswich, and found that, so far as his experiments went, the surface temperature in December was, generally speaking, higher than the underground temperature taken in places where there was practically no air-current passing. The deepest shafts observed were the Inglewood, Golden Crown, and Great Monkland. In the first mine, the surface shade temperature was 90 degs., and that at the 1,200 feet level, 78 degs.; at the Golden Crown, surface, 96 degs., and 1,200 feet level, 80 degs; and Great Monkland, surface, 80 degs., and 1,400 feet level, 76 degs.

The following "Note on the Antimony Deposit of El Altar, Sonora, Mexico," by Mr. Edward Halse, was taken as read:—

* *Trans. Fed. Inst.*, vol. iv., page 548.

NOTE ON THE ANTIMONY DEPOSIT OF EL ALTAR, SONORA, MEXICO.

BY EDWARD HALSE.

Some years ago, a heavy yellow mineral, found in abundance in the hills 50 miles west of El Altar, Sonora, was amalgamated for silver, and, as it was found to be very refractory, samples were sent to England for examination and analysis. The unknown mineral proved to be stibiconite, a kind of antimony ochre or hydrated oxide of antimony containing 75 per cent. of metal and 5 per cent. of water of combination. Stibiconite had hitherto only been found as a slight coating on some antimony minerals at certain localities in Bavaria, Arkansas, and Borneo, and its occurrence in workable quantity was therefore of great scientific interest.

About thirteen years ago some capitalists of Boston (Mass.) secured the control of nine antimony claims in the district. Each claim measured 800 by 200 metres—on three of them an outcrop of solid antimony was described as being traceable for many hundred feet in length.

While the workings were yet of a superficial nature they were briefly described by Prof. E. T. Cox, of Tucson, Arizona.*

For a time the deposits were actively worked, and a small cupola furnace was erected for the reduction of the ore at Oakland, San Francisco.

In 1882, a description of the process employed, with some further notes on the nature of the deposit, was written by Mr. J. Douglas, Jun.† Just previous to this, "owing to a disagreement with the mine owners and a consequent stoppage of supply," the works were closed down, and since then the mines appear to have been worked more or less intermittently.

In the Federal Government and State maps, the deposits are generally marked a few miles from the Gulf of California, on the eastern flanks of the Sierra del Alamo Muerto, which skirts the sea-shore.

Mr. Cox says that the geological features are similar to those of southern Arizona, and the mountains run in short narrow ranges, having

* *American Journal of Science and Arts*, series 3, vol. xx., 1880, pages 421-3.

† *Engineering and Mining Journal* (New York), 1882, pages 121-2. A brief description, taken from the Journal, is given in Mr. A. J. Phillips' *Treatise on Ore Deposits*, 1884, pages 566-7, but, by an error, it is placed under the heading of "United States."

for the most part a north-and-south trend. The crests are rugged or well-rounded cones. Between the ranges exists a *mesa* or tableland formed of the *débris* of the mountains. The material is so loose and porous that the small amount of water which falls through it leaves the land dry and arid.

Several species of cactus and mesquite, and small trees of hardwood known as *palo fierro* constitute the monotonous vegetation of the hills and plains.

To the north-west a wide desert region, the Desierto of the maps, separates the mines from the coast.

The mountains are of granite, flanked by sub-carboniferous limestone, in most places so crystalline as to obliterate all traces of fossils. Protruding through these and forming the mountain-peaks are porphyry, quartzite, basalt, diorite, and trachyte. Mr. Cox states that the country rock in the immediate vicinity of the antimony mines is quartzite and limestone—while that of the particular deposits examined by the writer appeared to be an altered eruptive rock (basalt or diorite).

The Boston Company controlled an area from 5 to 6 miles long and ½ mile wide. The veins are described as running nearly north and south and dipping east at a sharp angle, from 4 to 20 feet wide, and down to 30 feet below the surface the fissures were "filled from wall to wall with oxide of antimony, almost pure, and remarkably uniform in character."

In 1882, three systems of veins had been discovered within an area of about 4 square miles, viz.:—

1. San José, the most northerly, and most productive in antimony —non-argentiferous.
2. Santa Margarita group—argentiferous.
3. Argentina group—argentiferous.

A specimen well-coated with chloride of silver yielded 120·75 ounces of silver per ton. The silver lies chiefly as a distinct film (greenish in freshly-broken specimens, but which darkens on exposure to light) between the joints. It can be seen by the eye on compact broken surfaces.

The mines, examined about two years ago by the writer, are about 112 miles (43 Spanish leguas) west-north-west of the Santa Ana depôt of the Sonora railroad, nearly 50 miles west of the town of El Altar, and probably 30 miles (11 leguas) from the port of Las Salinas, and 10 to 15 miles from the coast. The deposits are found on hills about 700 feet above sea-level, and running parallel to the Sierra de las Palomas. The mineral occurs in loose stones (*boleos*) near the surface, and in veins,

of which there are several, running north-and-south, north-east and south-west (generally with a westerly dip), and east-and-west (with a southerly dip). The veins frequently intersect, and at these points the mineral usually occurs in bunches or pockets (*bolsas*).

In two of the mines, a fair amount of development work has been done. In one claim, a shaft has been sunk on the vein to a depth of 84 feet.

Two levels or *frontones* have been driven from this shaft on either side, proving the lode for about 100 feet in length. The vein appears widest and best in level No. 1 north-west, where it is 3½ feet thick, and composed of good mineral. On the opposite side of the shaft, the vein is 3 feet thick; here another vein intersects it, forming a pocket of mineral, and at this point the principal vein runs almost horizontally for about 18 feet, and then resumes the normal dip.

At and near the bottom, the vein is more quartzose, and bears much less mineral than in the upper level.

The general run of the veins is north-east and south-west (magnetic 1891) with a dip to the south-east of 52½ degs.; it has a fairly regular width (2 to 3½ feet), strike, and dip, and at one point has a very good and well-defined hanging-wall (*respalda*), but it varies a good deal in richness from point to point, and consists of bands (*hilos*) of black, yellow, grey, or brown stibiconite frequently much mixed with quartz.

The country appears to be soft and decomposed, and is probably volcanic. It varies from white to dark red in colour.

In an adjoining claim, a vein runs east-and-west, with a sharp southerly dip. A shaft has proved the vein to a depth of 150 feet, and shows it to be composed of bands of dark-coloured stibiconite and quartz. The latter increased in depth; the ore from the bottom of the mine consisted largely of this gangue and was too poor to work.

In another claim, one vein runs north-and-south and dips west, consisting of heavy yellow stibiconite, and another north-east to south-west dipping north-west.

A parcel of 50 tons of hand-picked mineral shipped to England yielded as much as 53 per cent. of metallic antimony, and sold for £10 2s. 6d. per ton.

It is estimated that the cost put on cars at the Santa Ana depôt would be about £6 per ton, which is prohibitive.

If practicable, it would be far cheaper to send the mineral to the port of Las Salinas, Gulf of California, a distance of about 30 miles, and to load on barques bringing merchandize from Europe. The total cost, including freight to Europe, would then be about £6 per ton.

Water is very scarce in this region, while, although there is probably sufficient wood (chiefly *palo fierro*) for the timbering of small shafts, galleries, etc, and for raising steam, or for making charcoal if necessary, large timber would have to be imported from the States. No doubt several thousand tons of this mineral could be raised at and near the surface by opencuts and by sinking, but it would seem from the trials already made that the mineral does not continue in depth, so that a large and constant output is by no means assured. The deposits, in fact, would appear to form the capping of quartz-veins, and it is quite problematical whether, below the water-level, the hydrated oxide will be found to give way to the ordinary sulphide (stibnite).

Mr. James D. Dana* describes stibiconite as "massive, compact, also as a powder and in crusts. Hardness, 4 to 5·5; specific gravity, 5·1 to 5·28.† Lustre, pearly to earthy. Colour, pale yellow to yellowish white, reddish white. Composition, probably $H_2Sb_2O_5$ or $Sb_2O_4 + H_2O$. Analysis, oxygen 19·9, antimony 74·5, and water 5·6, total 100. Usually more or less impure. . . . Pyrognostic character, in the closed tube gives off water, but does not fuse; on charcoal decrepitates, fuses with difficulty to a grey slag, and gives a white coating."

The Sonora mineral breaks with a rough conchoidal fracture. Prof. S. P. Sharples says it is only slightly soluble in hydrochloric or nitric acid, or in aqua regia; that fusion with bisulphate or soda only partially resolves it; that it readily decomposes in a platinum crucible with carbonate of soda. It is, moreover, easily reduced in a crucible with powdered charcoal or cyanide of potassium, giving as a single operation buttons of "star antimony."

According to Mr. Douglas the cupola used for smelting the Sonora ore was a round, close-fronted and water-jacketed furnace of the following dimensions:—36 inches in diameter, 6 feet from the tuyéres to the feed door, and 18 inches from the tuyéres to the bottom of the crucible. The tuyéres had a slight dip, the blast was from a No. 4 Root blower. The charge consisted of 80 lbs. of ore, 100 lbs. of slag, and 30 lbs. of coke. The slag was returned until it became too acid, when 10 lbs. of pure iron-ore was added to the next charge. The metal and slag were tapped into slag-pots. Seven tons of ore was on the average consumed by the furnace in twenty-four hours. An enlargement of the furnace-stack helped to save the antimony. The yield was 77$\frac{3}{4}$ per cent. of the assay value of the ore, or 40 per cent. of antimony.

* *System of Mineralogy*, 6th edition, 1892, page 203.

† A specimen from Sonora gave 5·07.

The coarse antimony was refined in a crucible—each being heated in a separate furnace. The charge in each crucible was 40 lbs. of coarse antimony, 2 lbs. of sulphide of antimony (pure native stibnite), and ½ lb. of carbonate of potash. The contents of the crucible were poured out into square moulds of the same size and shape as the English ones. The surface was beautiful and deeply starred. The slag removed from the cake was returned without addition to the refining-crucible, and to ten charges more, with the addition each time of a little stibnite and potash. The cakes were finally cleaned by scrubbing, which was a tedious operation.

In the autumn of 1881 the works were turning out about 10 tons of antimony weekly.

The metal obtained from the Sonora ore was pure, containing, according to Mr. F. Claudet of London, only 0·54 per cent. of impurities.

Another analysis gave impurities as follows:—

	Per Cent.
Arsenic	0·036
Copper	0·052
Lead	0·538
Iron	0·039
Zinc	none
Cobalt	traces
Nickel	none
Sulphur	0·254
Total impurities	0·919

The following paper on "The Choice of Coarse and Fine-crushing Machinery and Processes of Ore Treatment," by Mr. A. G. Charleton, was taken as read:—

THE CHOICE OF COARSE AND FINE-CRUSHING MACHINERY AND PROCESSES OF ORE TREATMENT.*

By A. G. CHARLETON.

Part V.—Gold-milling.

The writer will now examine the differences in details of milling practice which obtain in different parts of the world, considering the local conditions and character of the ore treated, in order to account for the diversities which exist.

General Details and Practices in California.

In this connexion, the writer begs to acknowledge his indebtedness to a paper on the subject by Mr. J. H. Hammond,† in the *Eighth Annual Report of the California State Mining Bureau.*

The California ores are mostly quartzose, carrying free gold and iron pyrites, sometimes accompanied by arsenical and copper pyrites, but more frequently galena and zinc blende. Auriferous tellurides and some of the rarer minerals are occasionally met with, but they are of little economic importance.

The vein-filling is sometimes countrified (consisting of wall-rock more or less altered) but is usually quartz, in some instances associated with calcspar, which, however, but rarely forms exclusively the vein-filling or gangue.

The value of the Californian gold ores varies between 14s. 7d. and £1 13s. 4d. per ton in the low-grade ores, up to between £3 2s. 6d. and £6 5s. per ton in those of high grade; £2 to £2 10s. is probably a rough average of the grade of ore at present treated. The percentage of sulphides (mostly iron pyrites) runs from 1 to 5 per cent. of the ore milled; 2 per cent. being an average approximation in all probability of its pyritous contents.

The saving of these sulphides, though small in quantity, is an important feature in the treatment of these ores, and therefore the majority of the mills of the State have their plants specially adapted to close-saving in this respect, although the value of the concentrates is subordinate to the free gold present in the ore.

* *Trans. Fed. Inst.*, vol. iv., pages 233 and 351; vol. v., page 271; and vol. vi., page 69. † *The Milling of Gold Ores in California.*

The average value of the concentrates being high, accounts for this, and may be put at £16 13s. 4d. to £18 15s. per ton. In the low-grade ores the gold occurs disseminated in particles through the ore, rarely visible to the naked eye. In ores of high-grade it is often found massive and sometimes in laminæ along the planes of division of the quartz (ribbon-rock), while in other cases it assumes the form of wire (filiform), and is also occasionally arborescent.

Specimen ore is often sold to jewellers, who pay from £4 3s. 4d. to £5 12s. 6d. per ounce for the free gold that the quartz contains. The pyrites is generally massive, though sometimes found crystallized, but iron pyrites of the latter character rarely carries much gold. The sulphides in the country-rock are likewise of little value.

In some of the Californian mills the rock-breakers are arranged in a way somewhat out of the common, but which is a very excellent one. The ore coming from the mine is discharged in the usual way on to a grizzly which separates it into two classes; what passes through goes to the main ore-bin (underneath at the back of the battery), while the coarser rock is retained in what is called the coarse ore-bin, behind the rock-breaker. The grizzly is set so as to form the bottom of the upper half of this last-named bin, the lower part and sides being boarded in.

A shoot leads from the door of the coarse bin (which is worked by a rack-and-pinion) into the jaws of the rock-breaker. By this arrangement the delivery of the ore is controlled, ensuring an almost continuous supply of stone to the machine, which greatly increases its capacity and reduces expense, as it saves the labour of a feeder which is necessary, where, as in most mills, the ore is discharged over the grizzly on to the rock-breaker floor, and also maintains a regular feed.* The only point to be observed is that the stone is sent to the mill spalled to a size which will all enter the jaws of a given-sized crusher.

At the North Star mill with this arrangement, one (15 inches by 9 inches) breaker crushes 30 to 40 tons of hard rock in 5 to 7 hours, effecting a saving in wages of two or three men as compared with the labour required ordinarily, while evidence of its uninterrupted work is shown by the fact that it requires 12 instead of 8 horse-power as is usually computed. The crushed ore joining the fines which have passed the grizzly, is well mixed, which ensures uniformity in the charges fed to the stamps.

* In some of the newer German concentration-works a reciprocating-table, at the end of the shoot, actuated by an eccentric, is employed to ensure this result.

Where fall permits, it may sometimes be found advantageous to crush coarse in one rock-breaker, and deliver the product to a second one, breaking it finer. This greatly increases the capacity of the stamps. The rock-breakers are usually set to crush to 2 or 3 inches. The shoes and dies last from six to eight months; and when made of steel they run about twice as long.

Self-feeders.—The use of self-feeder machines saves a large amount of labour, increases the capacity of the battery from 15 to 20 per cent., besides effecting a considerable reduction in the wear of screens, shoes, and dies.

Other conditions being equal, low feeding increases the capacity of the stamps, that is to say, the ore should be fed in regularly, and in small quantities at a time. When thrown into the mortar irregularly in large charges, the ore is piled up in the box, and the stamp cushions upon it, which impairs the effectiveness of the blow. The best hand-feeding is superior to mechanical devices, but men are mortal, and either through ignorance or inattention, caused by the extremely trying conditions under which such work must be performed for long spells at a time, the machine on the whole is the most reliable, apart from the monetary question of saving in labour where labour is dear.

Automatic feeders are of various types, those with a revolving-carrier (such as the Hendy Challenge) deserving the preference for wet, clayey and sticky ores. Those with a shaking-table, such as the Tulloch and the Stanford roller-feeder, give satisfaction, however, with certain classes of ore, and being the cheaper, are frequently employed. The Challenge feeder costs £52 1s. 8d. in San Francisco, occupies 23 cubic feet packed for shipment, and weighs 750 lbs.

The Hendy improved Challenge suspended-feeder does away with the underneath framing of the ordinary type of machine, and renders the feed-side of the mortars more accessible, the machine being supported on parallel tracks overhead, between the battery-posts and ore-bins. It is specially adapted for this reason for feeding rolls.

Mortars.—This important feature in battery construction depends on the character of the ore and deserves more consideration than it generally receives. Narrow mortars accelerate the discharge of the pulp, and are therefore disadvantageous, where it is desired to amalgamate on inside-plates, or settle coarse-gold in the box. They also occasion an excessive breakage of screens, adding to the expense of renewing and changing them, if the ore is of a hard flinty nature.

The liability of breakage can be reduced by raising the height of the discharge, but this counteracts the advantage aimed at in using a narrow mortar, viz., large capacity. Each mortar is fitted inside, with side and end-linings of cast or wrought-iron to protect it from wear. These linings when of cast-iron last six to nine months. In some mills they are held in place by bolts with the heads countersunk in a recess in the plate, which are tightened up from the outside; a better method, however, is to halve the plates together at the ends.

In many Australian batteries, a length of about 9 inches is cut out of the middle of the front-side of the mortar, and replaced by a dove-tailed iron casting of the same shape and thickness as the section removed. This slides up and down (bearing against a shoulder) when the screen frame is taken out, and facilitates cleaning the box at a general clean-up. When the sides and bottom of the false-section are properly planed and the opening trued up to correspond, the mortar remains perfectly watertight.

The height of discharge, *i.e.*, the vertical height of the lower edge of the screen above the die, should be regulated to correspond more or less with the width of the mortar, taking into consideration the object aimed at in the treatment of any special ore. Narrow mortars require a relatively higher discharge to avoid breakage of screens, and to prevent scouring the inside copper-plates. Having fixed on the proper height of discharge, it is most important to keep it uniform. There are various ways of doing this, which are referred to elsewhere. With ores quickly crushed and readily discharged, it is advisable to raise the height of the discharge, to retain the pulp in the mortars long enough for its proper amalgamation. Where an ore contains a high percentage of sulphides, and cannot be advantageously amalgamated in the battery, or where stamps are used with a view to large capacity in crushing, and it is desirable at the same time to catch the coarse-gold liberated, by allowing it to settle in the box, or in the third case of an ore containing brittle sulphides, which from being subjected to lengthy stamping are liable to be slimed, double-discharge mortars may be found advantageous. Stamps crush faster than the screens ordinarily discharge the pulp, with the result that many of the particles are subjected to unnecessary pulverization, sliming the sulphides which can with difficulty be settled, producing float-gold, and when coarse occasionally perhaps pounding it; hence double-mortars sometimes serve a necessary purpose. Their objections and limitations are: (1) where copper-plates are used inside, mortars of this kind are inconvenient, and are too roomy for efficient amalgamation; (2) owing to the extra water

they use, they are prejudicial to the outside plate-amalgamation, and in some cases to the subsequent concentration, depending on the character of the concentration-method, and the machines adopted to that end. The feed-opening of a mortar should extend nearly the whole length of the box, and be about 4 inches wide, allowing for the upper part of the back-lining.

Screens.—In California, various kinds of screens are used—steel and brass wire-cloth; slot and needle-punched (tough but soft), planished Russian sheet-iron (which has a smooth glossy surface), and tin. These last are not so thick as Russian iron and consequently admit of more rapid discharge than Russian iron for the same diameter of perforations, but they do not last so long. The numbers by which steel and brass wire screens are designated correspond with the number of meshes per lineal inch. The most common sizes in use in California are 30 and 40, No. 30 being made of No. 31 wire and 40 of No. 33 wire, the latter costing in San Francisco 1s. 6d. per square foot. Each battery takes 3 to 4 square feet.

The screens wear most at their lower edges. Brass wire-screens last 10 to 14 days. High discharge and wide mortars promote the life of the screens. One brass wire-screen, No. 30, bar accidents, will put 120 to 140 tons of ore through, before it is worn out. Steel wire is liable to rust, and is therefore not much in favour.

The area of discharge in wire-screens is much greater than in slot or punched iron, producing a more uniform pulp, hence it is in a condition particularly adapted to after-concentration. The numbers and sizes of needle-punched and slot screens correspond to the number of the corresponding needles which will pass through the openings. Nos. 5, 6, 7, 8, and 9 are the commonest sizes. The slots are horizontal or diagonal (angle slots). They are generally burred on the inside to prevent clogging, as the opening enlarges outwards, but this tends obviously to reduce the discharging capacity of the battery, from the fact that a particle of ore which does not strike the opening straight, has no chance of getting through; that is to say, either obliquely, or when flowing down the grating.

Russian iron screens last 15 to 40 days, a month being about the average. The screen-frames are of wood, and should have a batter of about 10 degs. projecting outwards at the top; they rest in a recess cast in the front of the box, and are held in place by wooden wedges driven under claws cast on the mortar. A strip of blanketing should be laid round the frame.

A piece of heavy canvas is generally hung across the front of the mortar.* Stamping should be carried just far enough for the proper liberation of the gold and sulphides from the veinstone. When the gold is finely divided, as generally happens in low-grade ores, the stamping must be proportionally finer than when the gold is coarse. When the sulphides constitute an important factor in the value of the ore it is desirable to crush coarse to avoid excessive loss by sliming them. That dead-stamping is a serious and by no means visionary fact is attested by the statement that generally over 80 per cent. of the ore discharged through a No. 30 screen will pass a No. 60, and often 50 per cent. will pass a No. 120.

TABLE OF SCREEN SIZES.

No. of Needle.	Corresponding Mesh.	Width of Slot. Inches.	Gauge of Russian Iron. No.	Thickness of Iron. American Gauge. No.	Weight per Square Foot. Lbs.
5	20	0·029	14	23¼	1·15
6	25	0·027	13	24	1·08
7	30	0·024	12	24½	0·978
8	35	0·022	11	25	0·918
9	40	0·020	10	26	0·827
10	50	0·018	9	27	0·735
11	55	0·016	8	28	0·666
12	60	0·015	8	28	0·666

Russian iron is sold in sheets measuring 28 inches by 56 inches, equal to 10·88 square feet. Some manufacturers' measurements differ somewhat from the table. The Attwood screen-measure is very convenient for determining the size of orifices. For inside battery amalgamation, the mortar is provided with strips of silver-plated copper-plate, back and front, seated on wooden blocks (provided with iron-facings where the keys come outside), resting on top of and flush with the inside liners (an Australian term for the lining-plates). Silver-plated brass screws are used to fix them on.

Drop of the Stamps.—This depends on the character of the ore, the speed and weight of the stamps, and the duty required, varying from 4 to 9 inches; 6 inches being about the mean in California. Sufficient drop must be given to produce a good splash. Soft and highly mineralized ores need a low drop usually. The order of drop is of importance, as on it depends an even distribution of the pulp on the several dies. Adjacent stamps should never drop consecutively, as this occasions accumulations of pulp in the end of the mortar, by which the efficiency of the stamps at

* In Australian batteries, a cover of sheet-iron or wood, hung on hinges (cast on the top front of the box) is used.

that end is reduced, whilst those at the other extremity are liable to pound iron. The order, 1, 4, 2, 5, and 3 gives a good splash, and gives satisfactory results. 1, 5, 2, 4, and 3 is also extensively adopted. The remedies, for a bad order of drop, are either to change it, re-cutting the key seats in the cam shaft (by no means a simple affair), or else to suffer the misfortune of having to give one stamp a greater drop than the others.

Duty of the Stamps.—This term, which is applied to the quantity of stone crushed per head by the battery in 24 hours, will depend on the weight of the stamp, number of drops, height of drop, height of discharge, size of screen-mesh, area of screen-opening, dimensions of the mortar and character of the ore. Clayey and hard ores reduce the duty. 2¼ tons per stamp in 24 hours is about the average duty of Californian batteries.

Speed of the Stamps.—Low speed is necessary with heavy stamps and high drops. In California, 900 to 950 lbs. stamps, with 6 to 7 inches drops, are run at 85 to 95 drops per minute. With double cams, the speed must not exceed a certain rate, for if the revolution of the cam does not give sufficient time for the stamp to fall, the descending tappet striking the toe of the returning cam, is very likely to cause a breakage or dislodge either boss, shoe, or tappet. A fast drop produces a good splash in the mortar.

The cam-shaft is generally made of mild steel, and the cams themselves may be made of hard chrome steel. The curve of the face should be a slightly modified involute.* The cam-shaft pulleys are best built up of wood, thoroughly seasoned, and the joints filled with white lead and oil. They are held by 3 feet cast-iron double sleeve-flanges. The hub is bored and fitted to the cam-shaft and fastened with a steel key. The outside flange is bored and fitted to the sleeve with a jib-headed steel key. Kiln-dried sugarpine is a favourite material for making these pulleys. Cams ought to last several years. Tappets should have both faces turned true, and be fixed on with a steel jib and two steel keys, bored accurately with the jibs in place, to fit the stems, and counterbored opposite the jibs by moving the centre ¼ inch, taking a cut ⅛ inch deep, with a diameter ⅛ inch less than the bore. This gives three bearing-points and allows the tappet to move easily on the stem.

* Split cams in case of breakage are more handy to change than solid ones.

The working-face, with the exception of a small annular ring next the stamp-stem, is subjected to equal wear, hence this central part is recessed out $\frac{3}{8}$ inch to $\frac{1}{2}$ inch wide and deep on both ends, so that the cam may not be worn down by the projecting ridge which would be liable to be formed on the inside of the tappet. Where one face is worn, the tappet is reversed. The tappets, like the cams, are usually made of hard steel.

The revolving cam in lifting the tappet causes it to partially revolve, communicating a certain amount of rotation to the stamp as it drops. Its chief importance is in equalizing the wear of the shoes and dies, which promotes better crushing. With an ordinary amount of grease on the cam, a stamp should make a complete revolution in four to eight lifts, but if there be an excess of grease, or the tappet has been allowed to become grooved, the rotatory motion is much impaired. The average life of the tappets is four to five years. They may be broken by being keyed too tight. When their faces are worn they are planed down. The importance of keeping the height of discharge regular is second only to maintaining a fixed height of drop. A frequent examination should be made to see that the cams have not shifted, which is very liable to happen if the tappets are not properly secured. The cams must be greased sufficiently, but not in excess; nothing is more disgusting or liable to interfere with amalgamation than grease being thrown on to the aprons or falling on the boxes.

The wooden covers of the mortar are no protection against oil, as the writer has seen it in some mills running down the stems; he may say that they were not American mills. Wooden finger-bars, fitted into latch-sockets lined with leather, hung on a wrought-iron jack-shaft at the back of the battery, are mostly used in America to hang up the heads. To perform this operation neatly, requires some skill, the battery-man standing on the platform at the back of the stamps just below the jack-shaft, and inserting a wooden lever with his right hand under the tappet as the cam comes round. This lifts the tappet higher than usual, allowing him to slip the point of the finger-bar underneath the back of the tappet, before the cam drops the stamp.

In Australia, a different method is generally employed. Two flat straps of iron are fastened to the battery-posts horizontally, a little higher than the full height of the throw of the cam (one at the back and one in front of the stamps). Resting across these straps are five rectangular bars of iron attached to each battery, provided with a hook at one end and a handle at the other. The hook slides on the front strap, and

the battery-man, taking the handle at the back in his hand and resting a short crowbar on the back strap, catches the tappet as it is raised, prizes it up slightly, and slips the cross-bar sideways underneath.

Shoes and Dies.—These are either of iron or steel. Ordinary cast-steel used for this purpose has a great tendency to chip and cup; recently, however, chrome-steel has come into the market, and in remote districts, where transport is an important item, it has replaced iron.

Steel shoes with iron dies wear more evenly than if both are steel. The life of steel is about two-and-a-half to three times that of iron shoes and dies, while the cost is about twice as great. The mixture of old chrome-steel shoes and dies with iron, produces shoes and dies which wear considerably longer than iron, and where there is no other means of utilizing the old castings this plan may be advantageously introduced. Old ordinary iron castings are sold to local foundries for 1½ to 2 cents per lb.

The shoes are made to fit into the stamp-head by being tapered so as to fit into the core of the socket, the shank of the shoe being surrounded with a number of dry hard-pine wedges attached to it with a piece of twine, upon which the boss is driven on by allowing the head to drop on the bare die. In Australia, in some mills, in place of wood-strips the shank is covered with canvas or blanket in strips, crossed at right angles, overlaying one another alternately, and tied round with thread. The heads or bosses are accurately bored at the top to receive the tapered end of the stem, and have a conical socket cored out at the lower end for the shank of the shoe. Transverse rectangular key-ways, 1 inch by 2½ inches, cross the centre of the head at right-angles, passing through the bottom of the recesses, in which the stem and shoe-shank fit, for the purpose of wedging these latter out with loosening-keys.

The durability of the shoes and dies is affected by the weight, speed, and height of drop of the stamps, the material they are made of, coarseness of stamping, and height of discharge, as well as the manner of feeding the ore and the hardness of the stone. Iron shoes of good quality will last 30 to 47 days; they are worn down usually to from 1½ inches to 1 inch in thickness, and then weigh about 20 to 50 lbs. The dies being protected by the bed of ore that covers them to a depth of 1½ to 3 inches wear longer, but when the length of the shoe is greater than the height of the die the actual life of the latter may be the shorter of the two.

The consumption of iron for shoes and dies per ton of ore crushed is from 1½ to 3 lbs. To obtain a maximum duty, the dies should be kept as high as is compatible with the safety of the screens, and with successful

battery amalgamation; if such be practised. Uniformity in the level of the dies is important, for should one die project much above the others no pulp will remain on it, and the shoe will consequently pound on the naked die. Stems are made tapered at both ends so as to be reversible, and are usually of mild steel. When broken they can be swedged or planed down, and additional lengths welded on if necessary.

Foundations, etc.—Nothing about a battery is more important than well-constructed solid foundations. The mud-sills and battery-blocks are generally made of yellow-pine, free from sap, or sugar-pine. Sugar-pine or red-spruce is used for the framing of the battery. Sun-cracks are filled with melted sulphur or Stockholm tar, laid on while hot. They should be bedded on concrete or on the clean bed-rock. An overhead travelling-crane on a suspended track should extend the full length of the battery. The battery-blocks for each mortar in California are generally made in two pieces each 30 inches thick, and wide enough to fill the space between the line-sills and battery-posts. They are secured with oak keys 4 inches wide, tapered from 6 inches in thickness at the head to 5 inches at the point as well as with six 1 inch bolts. Yokes of 10 inches by 10 inches timber are fitted and bolted to the line-sills and battery-posts. In loose ground the sides of the pit for the battery-blocks may be walled in at the sides and ends. Once the whole set of blocks is level sighted along the whole line (which is generally effected by nailing a board along the front, a short distance below the top, and sawing the projecting part off), the top is planed smooth, making it about $\frac{1}{16}$ inch hollow to prevent it from becoming rounded. It should be covered with sheet rubber $\frac{1}{4}$ inch thick, or tarred mill-blankets and sheet lead ($\frac{1}{8}$ inch thick) to form a seat for the boxes. Personally, the writer prefers the former. The mortars must be levelled true, both lengthways and across, inside.

Amalgam.—In battery amalgamation, the largest proportion of the amalgam is caught on the inside-plates, representing, however, a greater percentage if the gold be coarse, than when it is finely-divided. Width of mortar, height of discharge, nature of plates and attention given to them, and fluidity of the amalgam, all influence the ratio between what is saved inside and on the outside-plates. Sometimes from these causes more is caught without than inside the battery; generally speaking, however, in California 50 to 80 per cent. comes from the battery. The fluidity of the amalgam is generally caused by overfeeding quicksilver, but in tropical climates it is to some extent influenced by the season; being more fluid in hot weather.

The battery-amalgam is invariably richer than the plate-amalgam, its value increasing with the coarseness of the gold, and as might naturally be supposed decreasing with finely-divided alloyed gold. At the Original Empire and Star mills in Grass Valley, California, while the battery-amalgam averages £1 15s. 5d. per ounce, the plate-amalgam only runs 18s. 9d. Amalgam varies greatly in different clean-ups with ores from the same mine. The frequency of cleaning-up depends on the richness of the ore and local practice. The richer the ore, the more often it is necessary to clean-up.

The outside-plates and sluice-plates are usually cleaned up every 24 hours. The amalgam and skimmings are ground with the addition of quicksilver in the clean-up pan to soften and clean the amalgam. The surplus mercury is expressed and the balls retorted with those from the general clean-up. Ten to fifteen minutes are required to clean up each battery, the stamps being hung up and water turned off. The general clean-up is a fortnightly or monthly affair. Two batteries are hung up, the outside battery-plates and screens removed, and inside-plates and dies taken out. The inside-plates are laid over the sluice-plates and the amalgam scraped off, taking care not to scratch the copper. Where the outside-plates are not removable, they must be protected, after they have been cleaned, by boards laid across them before attempting to clean up the mortar. The linings of the mortar and dies must be carefully washed in a tub, and scrubbed down with a brush before replacing them. If any of the castings are imperfect they should be carefully probed. The battery-bottoms are carefully shovelled into pails and removed for treatment, and after sifting out the coarser part of the uncrushed ore, the balance, consisting of several pans full of medium, coarse, and fine ore, mercury, sulphides, amalgam, pieces of iron, steel, etc., from the different batteries, are run through the last box cleaned-up. The bottoms remaining in it, when these have been finally worked down are taken out, and the bulk of the worthless material panned-off, extracting the steel and iron with a magnet; or the bottoms may be run through a tom. What remains is then put through the clean-up pan. In large mills, the barrels and clean-up batea are used. The clean-up pan should be in a special room as close as possible to the battery, the floor being of cement to prevent loss of amalgam and mercury. It should contain two cast-iron tanks, 4 feet long, 3 feet wide, and 3 feet deep to prevent loss and leakage in panning-off. It is a good plan also to give the floor a slight slope towards a small tank cemented into it, to catch any mercury accidentally spilled.

In one corner is placed the clean-up pan before mentioned, (usually about 2½ feet in diameter), provided with hard iron drags.

The final residues from the battery are ground in this pan with mercury, the refuse run off, and the amalgam collected after one or two hours' grinding.

Three men can clean up a 40 stamp mill in this way in 5 to 7 hours, at which time advantage is taken of the stoppage of the stamps to make needed repairs, and to change shoes, dies, screens, etc., if required.

It takes from two to four hours to retort the amalgam in the silver retorts used in large mills. Small mills use the cup-shaped retort. The resulting bullion is weighed and the gold melted in plumbago pots, taking 1 to 2 hours. Borings are then taken, or the bar is chipped in several places, and several bullion-assays are made to determine its fineness.

Grade of the Plates.—The inclination given to the inside copper plates is very variable; for the outside plates, it varies with the sulphides in the ore, the amount of water used, and the fineness or coarseness of the gold. Sufficient grade is necessary to prevent the pulp settling on them. High sulphides and coarsely crushed ore requires a maximum grade. The frame supporting the plates, should therefore be constructed so as to admit of adjustment to suit the ore treated.

The usual grade of outside plates is $1\frac{1}{2}$ to 2 inches per foot. The apron-plate is generally given a grade of from $\frac{1}{2}$ to $1\frac{3}{4}$ inches per foot, $1\frac{1}{2}$ inches being about the average. The sluice-plates have usually a fall of $1\frac{1}{4}$ to $1\frac{1}{2}$ inches per foot. The end of the sluice-plates should be furnished with a mercury-trap. With most ores, steep grades and a minimum of water are to be preferred to lessening the grade, and using more water.

By this plan the gold is rolled, rather than swept along by the water, and better contact is secured.

Shaking-plates suspended on movable springs are an important adjunct to the system of amalgamation; they should be the same width as the sluice-plates, but set at a slightly less grade; the movement of the ore, being assisted by the longitudinal shaking movement given by the eccentrics which actuate them.

There should be one or two drops from 2 to 3 inches in height in the line of plates; a crater-like deposit of amalgam accumulating where the pulp drops from one step to another.

The frames of the plates, with the exception of the apon-plate, which is sometimes supported on a casting bolted to the mortar,* should rest on

* If the more common method of supporting the apron-plate like the lower ones is adopted, the end board ought to be brought well under the lip of the mortar, but kept from direct contact with the battery-blocks and the under side of the box.

bearings independent of the battery framework, to avoid the jar which would otherwise ensue. The plates are held down by wooden cleats at the side.

Mercury is charged every hour or so into the mortars, the quantity depending on the grade of the ore and physical character of the gold. Finely-divided gold requires more mercury than when it is coarse. Sulphide ores also require larger charges, as ores of that class have a scouring effect on the plates and carry off the quicksilver.

The condition of the outside-plates is a guide as to whether too much or too little is being used. The amalgam should be sufficiently pasty to adhere to them, but neither too dry nor fluid enough to roll off.

From 1 to 2 ounces of quicksilver ought to be added to the battery for each ounce of gold contained in the ore. The value of quicksilver fluctuates considerably.

The loss of quicksilver per ton of ore is very variable where amalgamation takes place in the battery. Sulphide ore, especially such as carries galena or arsenical pyrites, occasions a large loss of quicksilver. The large losses in the early attempts to amalgamate the mispickel ores of Marmora, Canada, is a striking case in point.

Loss of gold accompanies the quicksilver, but its amount is liable to be overestimated by some mill-men. The loss of mercury at the Empire and North Star mills is said to exceed that of any mills in California, but *per contra* there are few mills that save such a high percentage of the gold in the ore. Their loss is reckoned to be often as great as 1 ounce of mercury per ton of stone crushed. In other instances it varies from $\frac{1}{5}$ to $\frac{3}{4}$ of an ounce per ton; $\frac{1}{2}$ an ounce per ton or 1 lb. per 32 tons of stone crushed is about a mean. The general causes of this loss are referred to elsewhere.

Concentration.—The pulp in most Californian mills is conveyed from a distributing-box at the end of the copper-plates through 2 inches pipes to the concentrators. These have various devices for saving amalgam, free-gold, and quicksilver, that may have escaped the preceding appliances, as the pulp delivered to the concentrators ought not to carry these substances. Any quicksilver, lost by previous careless handling or imperfect amalgamation, that finds its way to the belt-concentrators is lost by volatilization in roasting the concentrates preparatory to treatment by chlorination, which is generally practised in California; and if the gold be coarse, whether it be free or amalgamated, it introduces difficulties into the chlorination treatment, hence the necessity of saving these substances before they get to the concentrator-belts.

There is no preliminary sizing of the particles of ore in Californian gold-mills, and therefore the conditions essential for perfect concentration are wanting. Despite this serious disadvantage some of the concentrators, such as the Frue-vanner * and Embrey, succeed in obtaining clean concentrates with but little loss of auriferous sulphides. Other concentrators in use are the Golden Gate, Duncan, and Hendy pan. The Frue-vanner and Triumph are, however, the most popular. Each has features of superiority, and each its advocates. Both have quicksilver and amalgam-saving devices.

The construction of these machines is too well-known to require to be detailed here. The author will only allude to one or two special points that may be noticed in their arrangement.

At the Empire mill a special arrangement is used for removing the sulphides from the belt and depositing them conveniently for shovelling into wheelbarrows. The specifically lighter particles are carried down the surface of the belt by the current, and pass as tailings to blanket-sluices outside the mill. Fine particles of heavy specific gravity have a tendency to cling to the belts, which promotes their recovery.

There should be a separate tank outside the mill into which the overflow from the tanks below the belts is conducted, so that the fine sulphides in suspension in the water may not escape. The consistency of the pulp and its even distribution across the belt must be carefully regulated. The speed at which the belt travels is also very important, varying from 3 to 12 feet per minute in the Frue, and 3 to 4 feet in the Embrey. The grade given to the belts should be properly adjusted, and the surface must be level cross-ways.

The clear water jets which dilute the pulp require $\frac{1}{2}$ to 1 gallon of water per minute. The depth of pulp or load on the belts is from $\frac{5}{16}$ to $\frac{1}{2}$ inch, and the feed-water amounts to 1 or 2 gallons. The capacity of the machines varies with the character of the ore; ores carrying a high percentage of sulphides, or mineral in a fine state of division (slimes) require more concentrators than when they are of an opposite character.

Two concentrators are the usual allowance for a battery of 5 stamps. A floor-space of 20 by 10 feet should be provided for each concentrator, and if a double row be used, they should be set head to head in front of the batteries, with a passage-way of 5 to 6 feet between them.

A point of the utmost importance is to secure intelligent supervision and regularity in running, and, to do this, power to run them should be

* The writer believes he may claim to have run the first automatic feeders and Frue-vanners which were operated successfully in a North Queensland battery.

supplied by an independent motor; for when the concentrators are connected with the main driving shaft, the stoppage of other machinery (such as a rock-breaker), has a disastrous effect on the work they do.

The number of oscillations given to the machines is likewise of consequence. With the Frue, it varies from 180 to 200 revolutions per minute, with a throw of 1 inch. In the Embrey, it is 230 revolutions. Three men, one head concentrator, and two assistants can easily attend to sixteen concentrators, *i.e.*, for a 40 stamp mill per 24 hours. The duty of the former is to supervise, repair, and oil the machines while the assistants rake out and remove the sulphides to the sulphide room.

In a large mill with 80 stamps, it is preferable to employ one man per shift to attend solely to the adjustment of the machines, and an engineer to make repairs for all the machinery about the mill. One roustabout can remove the accumulated sulphides. Adjoining the concentrating-floor, on a level with it and on the sunny side of the mill when practicable, there should be a room to store the sulphides, with a concrete floor to drain off the water to a central tank towards which the floor has a slight slope. It should be well lighted so as to dry the concentrates in the sun.

The concentrates in California are generally treated by the Plattner chlorination process (unless the mill is large enough to have chlorination works of its own) at custom's establishments. These establishments charge about £4 3s. 4d. per ton for treatment, and guarantee a return of 90 to 92 per cent. of the assay value of the ore.

Blanket-sluices.—The length of the blanket-sluices outside the mill is governed by the value of the tailings. From 100 to 200 feet usually suffice. These sluices have a grade of 1 inch to 1¼ inches per foot. The sands collected on the blankets are generally ground in a pan, with a diameter of 3½ to 4 feet, like a silver-mill pan. The pulp leaving the sluices constitute the mill-tailings, and to keep a proper supervision over the work, samples should be taken of those several times during the day and night, and their value ascertained periodically.

Mill-men are, on the whole, exceedingly remiss in this respect. An automatic sampler ensures the work being done properly. The McDermott and Starr machines are used for this purpose. The pulp is assayed three times a week, the samples being examined carefully to see to what cause the loss is to be ascribed. Microscopical examination of the sands should be made occasionally to ascertain if a perfect liberation of the free-gold from the gangue has taken place. Thorough and regular sampling is a check on the mill work, and causes the men to be alert and zealous in discharging their duties.

The wooden batea and miner's gold pan are used for panning-off.

The average value of the ore milled is represented by the value of the gold saved plus the value of the sulphides caught, and the value of the tailings. The percentage of gold saved by the mill is calculated from these factors, and represents the efficiency of the process. Other things being equal, it will vary with the class of ore, being less with brittle sulphides and fine-gold than when the opposite more favourable conditions obtain.

Most of the loss occurs through loss of sulphides, consequently a large percentage of rich sulphides, is liable to produce rich tailings. There are few ores in California, however, from which 80 per cent. and upwards of the assay value, cannot be extracted by careful mill-men in well arranged mills. The majority save 75 to 85 per cent. Exhaustive investigations, extending over 18 months, at the North Star and Empire mills, show a saving of 82 to 94 per cent. The usual percentage, according to reliable semi-monthly returns, is 86 to 90 per cent. In these estimates no deduction, of course, is made for any after loss in treating the sulphides; but this is usually unimportant, as before stated.

The mill labour in a 40 stamp mill per 24 hours is as follows:—

	£	s.	d.
One man at rock-breaker, at 10s. 5d.	0	10	5
Two amalgamators, at 12s. 6d.	1	5	0
Three concentrators, one at 12s. 6d. and two at 10s. 5d...	1	13	4
	£3	8	9

The rock-breakerman also attends to the blanket sluices, and is employed in other work about the mill. Where steam power is used, two engineers and one man to pile wood near the boilers, would be required in addition to the above staff.

The cost of milling per ton in a 40 stamp mill, with a capacity of 80 tons per 24 hours, driven by water power, therefore stands as follows:—

	s.	d.		s.	d.
Mill labour as above	0	10¼	to	0	10¼
Assaying, retorting, and superintendence	0	1¼	„	0	1¼
Supplies	0	3½	„	0	5
Quicksilver	0	0¾	„	0	2
Lubricants, screens, illuminants, machinists' time, etc.	0	2	„	0	4
	1	5¾	to	1	10½

To this must be added the variable cost of water-power. The use of steam-power would add about 5d. per ton to the above estimate for labour, with ½d. additional for repairs, lubricants, etc., incidental to using steam.

An electric plant to illuminate mill and offices costs about £125, the cost of producing the light being but little beyond the cost of extra power to run the dynamo. Good illumination is very desirable in a mill.

The charge for assaying, retorting, and superintendence is based on the salary of £25 per month for a man to perform these duties in addition to rendering other services, as clerk, timekeeper, etc., about the mine; one-half his time being charged to milling, the other half to the mining costs. At some works the mine superintendent performs these duties.

The power for a 40 stamp mill is calculated as follows:—

	Horse-power.
1 Rock-breaker	12
40 Stamps	66
16 Concentrators	8
8 Shaking-tables	2½
1 Clean-up pan	1½
1 Revolving barrel and batea	2
Total	92

Ninety horse-power will suffice if the revolving barrel, clean-up pan, and batea are run when the rock-breaker is thrown out of operation.

The use of water-power, when practicable, effects a saving in cost of plant, labour, fuel (the price of wood in California ranging from 12s. 6d. to £1 0s. 10d. per cord, and $\frac{1}{15}$ to $\frac{1}{8}$ of a cord being consumed per ton of ore crushed), repairs, and lubricants, decreases the liability of fire, affords a ready means of extinguishing conflagrations (reducing the insurance premium), and is more constant than steam. Where sufficient head is available, especially in dealing with a limited volume of water, hurdy-gurdy wheels, such as the Pelton, which develops 75 to 80 per cent. of the theoretical power of the water, and under the most favourable conditions even several per cent. higher efficiency, are to be recommended. For low pressures Leffels turbines may be advantageously adopted.

Copper-plates.—Nothing in milling practice gives greater trouble than keeping copper-plates free from yellow stain—electro-plating is beneficial; and another way out of the difficulty is to substitute Muntz metal for copper as a material for the plates, providing the ore is not excessively acid or of very high grade.

Muntz metal is an alloy of three parts of copper and two parts of zinc, a small proportion (less than $\frac{1}{100}$th) of lead being commonly added to it. Plates of this kind can be kept in good condition by using a weak solution of sulphuric acid, and are supposed to set up a slight galvanic action,

which keeps the mercurial surface in good condition. If Muntz metal be unprocurable all one need do is to take a metal that is positive to mercury, such as iron, and attach a strip of it in contact with the copper, at the head and down each side of the plate. This forms a weak galvanic couple, and in this way the oxidation being transferred to the more positive metal, the amalgamated surface of the copper will be protected from any acidity in the ore. In preparing copper-plates, advantage is often found in coating them at the start with silver, or better still, gold-amalgam, and the electro-plated copper-plates before alluded to are frequently used. There are different methods of amalgamating ordinary copper-plates, and the matter is of importance, as it has been found that when prepared with nitric acid they seem most liable to tarnish. A plate prepared with cyanide of potassium remains bright longer, whilst one which has been brought into condition with zinc-amalgam appears to stand better still.

The best results seem, however, to be obtained by using mercury in which a little cadmium has been dissolved, which can be advantageously used in small quantities both on the apron and in the mortar.* The vibrating amalgamated copper-plates, of which mention has been made to which an adjustable pitch can be given, mark a decided advance in battery amalgamation.

Copper-plates for amalgamating should not have been hard-rolled. To make them properly porous they ought to be annealed before use, heating the whole surface uniformly, and taking care that it does not get oxidized. They should weigh not less than 3 lbs. per square foot, and, within reasonable limits, the heavier they are the better. When laid smooth and true, the first dressing may be applied, by first scouring well with sand and wood-ashes, or they may be rubbed with fine emery powder, and washed with soda to make them perfectly clean and bright. After this, wash with clean water, and rub over with a solution of ½ ounce of cyanide to a pint of water. Follow with a second washing of water applied warm, to remove the excess of cyanide, and rub on a mixture of fine sand and powdered sal-ammoniac, together with a little mercury, with a piece of blanket or a hard brush. Sprinkle the plate over with mercury, and allow it to remain on half an hour, then wash off the sand.

* In some cases it is found beneficial to add about 4½ inches of a stick of sodium, ½ an inch square, to a flask of mercury to quicken it, but it must be done gradually in an open dish, holding the sodium in a cleft stick, as the action is very violent. The exact quantity must be found by experiment, for too much will cause great loss of mercury and gold.

Rub it over again with the cyanide solution, and add as much more mercury as the plate can absorb. Silver-amalgam can be best laid on with a little sal-ammoniac, using a piece of rubber belting.

Narrow mortars, low discharge, and excessive quicksilver feed (which produces a fluid amalgam) decrease the percentage of the amalgam caught in the battery boxes.

Too thick a layer of hard amalgam should not be allowed to accumulate on the plates permanently. To remove it, the plates may be occasionally immersed in boiling water until it is sufficiently softened to be easily scraped off. This is better than the ordinary method of sweating them.

The sweating of the outside battery-plates and aprons of a 20 stamp mill, after running for 18 months on £3 15s. ore (notwithstanding the fact that the plates were daily and carefully cleaned), has been known to yield £4,000 worth of amalgam.

It is therefore only the "tenderfoot," or the "new chum," who would sell his old plates, much less accept the philanthropic offer of new plates for old ones (unless he had first previously sweated them himself, and then it is doubtful that he would be the gainer), unless they were thoroughly worn out.

A convex curve formed by reducing the pitch of the fixed plates will sometimes have a beneficial effect and save gold-amalgam, which would otherwise be lost. This was proved by experience at the Spanish mine. It appears a mistake to follow up the aprons with narrow-plated sluice-boxes with the object of catching fine gold. It would seem more rational to diminish the velocity of the current by spreading it over a wider surface of smaller length. In Australia, it is a common practice to arrange the aprons in steps, with a fall of 2 or 3 inches at the head of each, the pulp falling vertically on to the coppers through an iron grating made slightly convex, which is punched with $\frac{1}{4}$ inch holes, and is supported across the head of the apron, so as to catch the discharge from the step above. The amalgam collects in thicker ridges below this grating, than on the lower surface of the plate.

No one who has been through different gold-mining camps can escape noting the fact that a modern stamp mill fully equipped with improved labour-saving appliances, and arranged so as to give the maximum of efficiency and economy, is comparatively speaking a rarity. There is more difference between the work done and results obtained, from a badly constructed and carelessly arranged stamp mill and those from a model battery, than there is between the latter and some other perhaps more efficient type of reduction process.

Day by day, milling becomes more systematically managed and scientifically worked. There is a tendency towards an increased use of wire-gauze screens in wet-crushing mills in some parts of California. They ought to give a higher duty, as the area of the openings is larger in proportion than in punched plates, and they show no tendency, as was formerly thought, to amalgamate the brass wire, which would destroy and choke them rapidly.

The necessity has been pointed out elsewhere of determining how much gold is being lost in the tailings, and an examination should be made as to the manner and cause of loss, with a view to seek a remedy.

The method of conducting such an investigation is as follows:—

1. Obtain a fair average of the daily tailings sample. Pan this down carefully to ascertain if free-gold, amalgam, or mercury is escaping. If there is an apparent loss the man in charge should be either replaced or instructed in his business.
2. A quantity of the average sample is next sized by passing it through, say 60 and 100 mesh wire screens, and each of the three sizes resulting, is weighed to determine the relative proportion of each, and assayed separately. If the sample which does not pass the 60 mesh screen, assays appreciably more than the finer sizes, the loss is evidently through enclosure in the particles of gangue; in other words through the ore not being reduced fine enough; and may be owing either to the free-gold or sulphides present. The sample should therefore be pulverized finer in a mortar to see whether it is to be ascribed to the one or to the other possible cause. The result will show whether finer crushing is likely to be productive of gain by amalgamation. If the assays of the three samples are nearly alike, finer crushing would clearly be disadvantageous, reducing the capacity of the batteries and promoting liability of loss. If the pulp passing the 100 mesh sieve goes highest, a coarser screen may be tried as likely to give increased capacity without extra loss.
3. A weighed portion of the original sample should next be panned-off to determine the percentage of sulphides present. The sulphides collected are then assayed to determine their value for subsequent treatment. In this connexion, test 1 must have been previously made, as any amalgam would, if present, lead to an entirely erroneous conclusion in estimating the value of the concentrates collected.

4. Note the loss of fine-gold in the slimes, as shown by the assay of the ore screened in the second test, and determine as nearly as possible by careful panning and assay of the concentrates after amalgamating the free-gold by hand, what proportion of the loss is due to the combined and what to the free-gold.
5. If the loss is high both in the slimes and coarser sizes, the gold is probably in a condition not susceptible to amalgamation, and if after trying the remedies that will be presently pointed out, no better results ensue, a small pan test may be made in the laboratory. In searching in this direction for a more perfect result the extra profit must, however, be carefully weighed against the additional cost.
6. Assays and analyses of the gangue and its component minerals, and a microscopical examination of the actual character of the gold, may in some cases give valuable assistance in enquiries of this nature.

The causes of loss have been stated in the earlier part of this paper as being due to (1) floatation; (2) enclosure in particles of gangue; (3) inaptness of the gold to amalgamate; (4) impure mercury; (5) bad condition of the plates; and (6) by its escape with mercury.

The loss from the first cause will generally increase, as pointed out by Mr. C. H. Aaron in the *New York Mining Journal*, August 10th, 1889, (*a*) with the fineness of the gold; (*b*) in absolute quantity, though not in percentage, with the richness of the rock in gold of this latter description; (*c*) in percentage, but not in absolute quantity, with the poverty of the rock in fine-gold; (*d*) with the quantity of water used; (*e*) with the muddiness of the water, hence a medium must be found in this respect so as to dilute the pulp as far as possible without running the danger of sweeping it away with too strong a current, (it is particularly in this connexion that shaking plates are of service); and (*f*) on the degree to which coarse particles of gold and amalgam are abraded and comminuted by the stamps, which is a strong argument against amalgamating as much as possible in the mortars using fine screens, with high discharge, and a minimum of water in the battery, except under special circumstances that justify it.

The loss from the second cause (enclosure in the particles of gangue) can only be remedied by finer crushing. There is a limit to this being done, however, as the finer the stone is crushed the finer will the particles of gold be reduced as well as the rock, the smaller will be the output of the battery, and the gold obstructed by the fine particles of gangue with which the water is surcharged, will have less opportunity of settling and

amalgamating. In such a case the rock may be submitted to two distinct operations of crushing and amalgamation with an intermediate separation of the slimes, but this entails extra expense which must be set against the additional saving effected.

At the Plumas Eureka mill, the tailings of the battery, as a case in point, are taken up by Italians (who pay a royalty for the privilege), and passed into wide shallow sluices which retain the sand while the slimes escape. The sands are then ground and amalgamated in arrastras.

Inaptness of the gold to amalgamate, the third cause of loss, may be overcome chemically or mechanically. In the latter case, by passing it through a machine such as a pan or mill, in which it is ground and brightened, or by warming the battery water if the inertness of the amalgamation be due to cold. If, however, this difficulty is of a chemical nature, advantage may be found in allowing a small stream of potassium cyanide to trickle from a tank into the battery, but care must be exercised in its use, or a fresh source of loss, from gold being carried off in solution, is liable to arise.

A little red oxide of mercury dissolved in the potassium cyanide will cause every particle of free gold exposed, to be instantly coated with quicksilver, and is efficacious where other means fail, but the use of such reagents is costly.

The precipitation of lead or copper in the mortars may be prevented by adding soda or milk of lime to the water used, or by causing it to flow over broken limestone, if the difficulty be merely in the water itself.

As regards impure mercury, the fourth cause of loss, the presence of lead, copper, mercurous oxide, sulphur, etc., is admitted to be injurious. Sometimes an ore contains sulphate of lead, which being to some extent reduced by the iron of the battery, will amalgamate with the quicksilver. In a similar manner soluble salts of copper either in the ore or the water cause a precipitation and amalgamation of the copper, which, though less harmful than lead, is still injurious. In all such cases the quicksilver after being strained should be purified before re-use.

To remove small quantities of copper and lead from mercury, retorting is not necessary. Such impurities may be eliminated by keeping the mercury for some hours in an enamelled pot, under dilute nitric acid (which is best warmed), and occasionally the mercury should be stirred. The acid will dissolve the copper and lead until it becomes saturated. It may also dissolve some mercury, but this will be deposited again when a fresh lot is treated, or it can be recovered by immersing a strip of copper in the liquid.

As the amalgam removed from the plates is liable to contain a little copper, it is well to always keep it in stock under acid. When wanted for use it should be washed with clean water. Oxygen, sulphur, and chlorine may be removed from quicksilver by adding a little sodium amalgam, avoiding an excess. Lead is not wholly removed by retorting, unless the quicksilver be covered to a depth of an inch or two with powdered charcoal.

If a solution of potassium cyanide in which red oxide of mercury has been dissolved is used in the pans (as is sometimes done, with the object of facilitating amalgamation), a little zinc-amalgam should be added to the pan towards the close of the operation, to avoid loss of gold in solution.

With regard to the fifth cause of loss, Mr. E. B. C. Hambley, in trials made at one of the Indian mills, in 1886, by substituting efficient for inferior plates, and looking after them properly, succeeded in saving 63·23 per cent. of the total gold caught, as compared with 33·33 per cent. yielded previously.

When ore is crushed dry there is great danger of loss, owing to fine particles failing to become thoroughly wetted, in consequence of which (although specifically heavier) they will often float for a long time on the surface of the water.

The sixth cause of loss, that of quicksilver carrying gold, may often be caused in the same way by flowering, owing to its attrition in water with sand, powdering it to an almost impalpable dust. The loss in itself may not be a serious item, but when charged with gold it is one of some moment, as it has been proved at the North Star mill, Nevada County, that £10 8s. 5d. worth of amalgam escapes the aprons and sluices which would be lost but for the shaking-aprons and concentrators below, intervening between the tailings-race and the battery.

Another loss of mercury occurs in handling, and a third in retorting the amalgam, a portion remaining unexpelled from the bullion, and some escaping condensation. At the Keystone mill, 10 ounces per month are lost in this way. Minor sources of loss are oxidation, sublimation (extremely slight at ordinary temperatures), combination with base metals in the ore, and adhesion to metallic particles in the gangue.

What is true in regard to not cleaning the plates too frequently does not apply to the battery, as it is generally beneficial, more especially if the ore contains coarse gold, which is caught in the box, to clean it out every two or three days, notwithstanding the loss of time.

The common practice of running for a month without a clean-up of the boxes, is in such cases bad, as the amalgam runs a great chance of being flowered and thrown out of the mortar, resulting in loss. Steel tappets and

cams are coming into general use, and it is an advantage to counterbore them. Split cams are convenient for changing if a breakage occurs.

Though the hardness of quartz as tested by scratching is nearly uniform, the facility with which it can be crushed depends on its texture, *i.e.*, its friability or compactness. The smaller the rock is broken, to a uniform size before it goes to the battery, the lower and more uniform will be the feeding, admitting of lower and more rapid drop. Hence more ore can be crushed for the expenditure of a given amount of power.

Battery Water.—The amount of water fed to the battery depends on the number of stamps in each battery, character of the ore, size of screen, and discharge of the mortar. Clayey and highly mineralized ores require a maximum amount, and a roomy, long or double-discharge mortar, more than a narrow single-discharge type. The quantity used per ton of ore stamped in California runs from 1,000 to 2,400 gallons. The mean amount is about 1,800 gallons. From ¾ to 1½ miner's inches per battery should be provided; a miner's inch is about 16,800 gallons supplied per 24 hours.

Practice in Colorado.

The following interesting particulars, chiefly taken from a series of papers on variations in the milling of gold ores by Mr. T. A. Rickard, which appeared in the *New York Mining Journal* in 1892 and 1893, illustrate the differences that obtain in milling practice in Colorado, Australia, and New Zealand.

At the Hidden Treasure mill, the stamps of the old batteries are furnished with screw tappets which have given place in the newer ones to the gib-and-key method of attachment. The stamps weigh 550 lbs., fall 30 to 32 times per minute, and drop in order 1, 5, 2, 4, 3. Each stamp makes from 1¼ to 1½ revolutions at each fall, depending on the amount of grease in the cam shaft. The discharge, measured from the top of the die to the bottom of the screen, is 13 inches when new dies have just been put in, increasing as they wear down to a maximum of 15 to 15½ inches.

The shoes are 5½ inches deep, and 8 inches in diameter. The dies are plain and cylindrical, fitting into a round seat in the mortar bed. They are 3½ inches deep, and slightly wider than the shoes, and are kept in place by being tightly packed round with tailings. The shoes weigh 83 to 86 lbs. each, the dies from 46 to 48 lbs., both being made of locally manufactured cast iron. The wear of the shoes is 11·3 ounces of iron per ton of ore crushed, that of the dies 4·5 ounces. At present fifty heads are employed on custom work, and these crush faster than the twenty-five fed with mill-rock from the California mine.

COMPARATIVE TABLE OF GILPIN COUNTY MILLS.

Name of Mill.	Hidden Treasure.	Gregory Bobtail.	Randolph.	New York.	Prize.
Number of stamps ...	75	125	50	75	25
Weight of each stamp (lbs.)	550	550	500	600	500
Number of drops per minute	30 to 32	27 to 30	30	26	28 to 30
Height of drop (inches) ...	16 „ 18	16 „ 18	16 to 18	18 to 20	15 „ 17
Depth of discharge at issue (inches)	13 „ 15	11 „ 13	14 „ 16	13 „ 15	13 „ 16
Capacity per stamp head (tons)*	1·14	1·04	·93	1·07	0·80
Capacity of entire mill (tons)	85	130	48	80	20
Size of screen (No.) ...	1½	1 & 2	1½	1½	1½
Description of screen ...		Burr slot	alternate	punched.	
Percentage of concentrates per ton of ore	13	14	20	15	12
Value of concentrates per ton	£3 2s. 6d.	£2 1s. 8d. to £5 2s. 2d.	£2 1s. 8d.	£1 9s. 2d. to £2 1s. 8d.	£2 1s. 8d. to £5 4s. 2d.
Percentage of bullion obtained in retorting ...	40	40	33 to 47	40	35
Fineness of bullion (per 1,000)	782 to 786	800 to 850	750 „ 850	750 to 800	750 to 775
Life of the screens (days)	81	60	16	25	75
Loss of mercury per ton of ore (dwts.)†	4·3	5·2	9·8	3·7	9·7
Consumption of water per stamp per minute (gallons)	2	2·3	1·4	1·3	1·5

Custom milling is a great feature of the mills of this section. The charges are £1 11s. 3d. per day per battery of five heads, including the concentration of the pyrites and their shipment on the railway cars. For small lots the rates are £5 4s. 2d. per cord for milling and 8s. 4d. per cord for concentrating. This last charge varies from 4s. 2d. to 12s. 6d. according to the percentage of pyrites present.

The cord of mill-rock above alluded to is equal to 7½ to 8 tons, while one of smelting ore averages 9 to 10 tons. The screen is of the burr-slot description, the slots being horizontal and alternating. No. 1½, equal to a 50 mesh wire screen, is usually employed. The screen surface is 4½ feet by 8 inches, 200 feet of screens being used up in a year equivalent to 66·6 screens annually. The average life of a screen is therefore 81 days. With the ore from the California mine they last three months by turning the lower portion, which wears most rapidly, to the top. The amalgam

* 2,000 lbs. each.

† Mercury is sold by avoirdupois weight—a bottle contains 76½ lbs.

yields 30 to 50 per cent. of bullion, which contains in addition to the gold, 207 to 211 thousandths of silver. Six and a half bottles of quicksilver are lost annually, representing 4·3 dwts. per ton of ore crushed by 75 stamps.

Most of the gold is caught in the mortar-box, which is effected to a slight extent by the free mercury added, but chiefly by two amalgamated plates arranged along the front and back of the box. They are both of plain copper, both 4½ feet long, the back one being however 12 inches wide, the front one 6 inches. The former is set at an angle of 40 degs., the latter nearly vertical.

The front of the battery above the screen frame is covered with canvas, by lifting-which the mill man can introduce his arm, and tell by the feel of the front-plate whether the right quantity of mercury has been added by the feeder. This saves stoppage of the battery and removal of the screen. On the average, the feeder adds half a thimbleful of quicksilver every hour. A test has shown that in crushing 8 tons of ore, carrying ⅛ ounce of gold per ton, 4½ ounces of mercury were added. After the first six hours a drop as large as a medium sized pea added every hour sufficed.

The gold-saving appliances following the battery are amalgamating tables, blankets, and concentrators. The first of these are 12 feet by 4 feet in one length, covered with copper, with a grade of 2⅛ inches per foot, which is greater than in California.*

In crushing 24 tons of ore carrying ½ ounce per ton, it was found that one such table required 5 ounces of mercury to dress it, whilst 3 ounces were used in dressing the front inside-plate, and 4 ounces for the back one.

The blanket-strakes or strips are 3 feet long and 18 inches wide. They are washed three times per 24 hours and serve to arrest any escaping amalgam mercury, rusty gold and the heaviest pyrites, together with particles of stone to which gold is still attached. Unless to save this last class of material, concentrators could replace them without loss. From the blankets the pulp passes to concentrators known locally as bumpers, a variation of the Rittinger.

In the Hidden Treasure mill there are 5 of these tables. The speed is regulated by the percentage of pyrites present, averaging 130 strokes per minute. Of the total amalgam obtained, $\frac{8}{9}$ is yielded by the inside-plates. On cleaning-up, the sand found in the battery round the dies is not panned but returned to the mortar. The outer tables are cleaned-up every 24 hours, but the inside-plates only every 48 hours. With poor

* Page 306.

ore the last named period is prolonged. At the general clean-up the amalgam from the plates is placed in a mortar and ground with hot water till of even consistency, the dirty water being decanted and mercury afterwards added to thin the amalgam.

Thus prepared it is run from one porcelain dish to another several times, and as the dirt and pyrites rise to the surface they are skimmed off by hand. The clean amalgam remaining is pressed through canvas. The skimmings resulting are re-introduced into the mortar and re-ground with fresh mercury and hot water. When fairly clean, a bit or two of potassium cyanide is added to render the mercury more lively.

In retorting, the retort is either chalked or lined with paper. The balls of dry squeezed amalgam are introduced into the retort, broken with an iron rod, and pressed down till hard and uniform. The cover is then put on and luted down with clay. Fine pan-sludge is often used in Australia, and forms a good lute. The only chemical used is potassium cyanide. Of this twenty-six 10 lbs. canisters were used in a year in the treatment of 28,793 tons of ore crushed. The tables are dressed every 12 hours with a weak solution containing 2 ounces dissolved in 3 gallons of water. The tables are brushed twice daily with a mop, mercury being sprinkled over them if the amalgam be too dry. The feeding is done by hand, and there are no rock-breakers. Feeders are paid 12s. 6d. per shift, and there is one for every 25 stamps. The mill is worked four months in the year by water power, four months by steam, and four months by both combined.

Firewood costs 19s. 9½d. per cord delivered. The cost of milling in 1890 was at the rate of 3s. 6d., but in 1891 it was decreased to 3s. 3d. per ton. The labour employed is thus distributed per month of 30 working days, 75 heads. One mill-man £36 9s. 2d., 1 assistant £20 16s. 8d., 6 feeders (3 per shift) at 12s. 6d. per day, £112 10s. per month, 2 concentrator men (1 per shift) at 12s. 6d. per day, £37 10s., total £207 5s. 10d., or 1s. 7d. per ton. Twelve hour shifts are worked.

While all the mills of the district are much of the same type and are engaged in crushing ore of much the same character, there are slight differences of detail in them. The stamps are all of light weight, rendered necessary by their high drop, which would be impossible with stamps of 850 to 900 lbs. The speed is also directly affected by the same cause, for the work required to lift the heads to a height of 16 to 18 inches prevents the rate of fall exceeding 32 drops per minute for good work, 40 is probably the practical limit, but the present tendency is in favour of keeping

it up to a speed of 32 drops, rather than running slower. The New York mill has the longest drop, but in this respect it follows the older practice.

The Gregory Bobtail mill fairly indicates the construction of the most recent plants in regard to depth of discharge. The precentage of concentrates obtained from the ores of this district ranges from 12 to 20 per cent., showing the refractory character of the mill-stuff. The value is very low, averaging £2 1s. 8d. to £2 10s. net per ton. The concentrates and blanketings undergo no further treatment, and are shipped direct on railway cars from the doors of the mills to the smelters at Denver. The freight is 6s. 3d. per ton, and cheap concentration supplemented by light smelting charges, alone makes the treatment of the concentrates profitable. Ninety-five per cent. of the silver and gold contents as fixed by assay is paid for, £1 13s. 4d. being deducted per ton for treatment; formerly a minimum rate of £1 10s. 2½d. was allowed, when this class of material was less plentiful. The retort percentage depends on the coarseness of the gold and the thoroughness with which the amalgam is squeezed, imperfect manipulation causing a difference of as much as 10 per cent.

The small capacity of the mills, the slight use made of the blankets, and the high slope of the amalgamating-tables (1⅛ to 2⅛ inches per foot), considering the deep discharge, account for the comparatively small amount of water used, viz.: 1½ to 2⅓ gallons per minute per stamp. The screens are of local manufacture, and are made of planished iron (an imitation of Russian sheet), size No. 24. The openings are straight slots set alternately. Nos. 1, 1½, and 2 most in use, are considered equal to 60, 50, and 40 wire mesh; they have nothing like the same discharge-surface however; a large proportion of the pulp being kept in the box till it would pass a 100 mesh wire screen. Their use is only justified by the main idea of Gilpin County practice, that of retaining the pulp inside the box till it is amalgamated. The side which carries the burr edge of the punched openings is always placed facing inside, to break the pulp and prevent choking.

There is a wide difference, as will be seen from the table, in the life of the screens in the different mills—far greater than can be explained by the greater or less attention of the mill-man, and the extent to which he is willing to allow the screen-slots to be enlarged by wear. Mr. Rickard accounts for this by their order of succession of the mills along the creek which supplies them with water. The Hidden Treasure mill receives water comparatively clean, and after having used it returns it to the

creek with a certain percentage of sulphuric acid, derived from the contact of the water with the pyrites. It is not surprising therefore that its screens last the longest—81 days. The Prize mill, in the same way, adds its quota of sulphates to the water, to the additional injury of the Gregory Bobtail screens, which only last 60 days.

The lives of the screens of the New York and Randolph mills are measured by days (25 to 16) instead of weeks, owing no doubt to the additionally corrosive action of the water lower down, due to the acid waters which issue from the underground workings of the Gregory mine above them. Taking the Hidden Treasure as most truly typical of the life of the screens in this district, we find 432 tons of ore pass through a grating before it is worn out. At Grass Valley, a screen will live to pass 200 tons, and at Bendigo (Australia) 134 tons. The very roomy character of the Colorado mortar-box probably accounts in part for this favourable comparison.

The loss of mercury is greatest in the mills with the deepest issue, which bears out what has been said elsewhere as to the danger of stamping it to flour, *i.e.*, subdividing it into minute globules, which are liable to become coated with pyrites or foreign matter, and are then borne away by the water. The variable loss of mercury at different mills may also be largely explained by the larger number of clean-ups where more lots of ore are treated coming from different mines, which lead to additional manipulative losses.

The ore of the California mine, treated at the Hidden Treasure mill, is representative of the ore of the district. It consists roughly of 15 to 20 per cent. of quartz, and 60 to 70 per cent. of vein-filling (other than quartz), an altered form of the rocks enclosing the vein. As these latter consist of gneiss, alternating with granite and mica-schist, the gangue is largely felspathic.

Of the metallic constituents of the ore, iron and copper pyrites predominate; grey copper (fahlerz or tetrahedrite) arsenical pyrites (mispickel) and galena are also present in noteworthy proportions. Blende is sometimes seen and chalybite (carbonate of iron) appears occasionally. The grey copper, which is here antimonial, is generally remarkably favourable for the presence of gold, a fact which would prove a valuable index in selecting the ore, were it not so often confounded with arsenical pyrites. Quartz (especially favourable when of a blue tint) is always associated with the pyrites in rich ore. The writer may here remark that he has observed this same peculiarity of colour in the rich quartz of the Mysore mines in India.

The following results of assays made by Mr. Rickard, upon a typical piece of ore broken in the 1,700 feet level of the California mine, throws some light on the distribution of the gold and silver :—

Mineral.	Gold. Ozs. per Ton.	Silver. Ozs. per Ton.	Remarks.
Iron pyrites	0·65	4·85	White coarsely crystalline.
Copper pyrites	0·85	53·50	Flaky dark yellow.
Grey copper	0·90	38·65	Chiefly covering the last.
Blende	0·16	6·45	Black crystalline.
White quartz	3·32	7·35	Opaque massive, with small
Bluish quartz	3·56	5·84	crystals of pyrites throughout.
Flinty quartz	0·18	1·90	Brown vitreous.
Felspathic gangue	0·90	2·35	Soft granular white.

This analysis bears out the experience of the mills, half the gold-contents of the being are extracted by the first amalgamation in the mortar box. The gold cannot therefore be chemically combined with the pyrites. On the other hand, the more highly mineralized the ore the richer it usually is also. There is no doubt the silver-contents are for the most part associated with the copper-bearing minerals, while the gold is enclosed in the quartz, especially when that quartz is immediately associated with pyrites. Neither blende nor galena is an attendant upon the gold, and both are a nuisance in the mill.

The following figures, representative of the output for 1890, further illustrate the nature of the ore—150·44 tons of smelting ore averaging £19 6s. 7½d. per ton net; 1,376·03 tons of concentrates averaging £3 2s. 9d. per ton net; 10,320·57 tons of mill-stuff averaging £1 10s. 11d. per ton.

The smelting ore is the high grade sulphide ore picked out at the mine and shipped direct to Denver. The mill-stuff yielded 4,766·39 ounces of bullion, worth £3 9s. 4½d. per ounce. Of the total tonnage, 90 per cent. was mill-ore, representing 84 per cent. of the total value. The mill-ore yielded 13 per cent. of concentrates.

A test made in March, 1891, to determine the completeness of the mill extraction on a lot of 8,400 lbs. of ore, which contained 4 per cent. of moisture (leaving 8,064 lbs. net) showed, after passing through a breaker and rolls (specially erected for accurate sampling), an assay value in gold of 1·85 ounces, and in silver of 8·75 ounces per ton.

The contents of the 8,064 lbs. were therefore 7·46 ounces of gold and 32·86 ounces of silver. At the smelter such ore would be worth £5 12s. 10d. per ton net (smelting charges being £2 10s. per ton and 95 per cent. of the gold and silver being returned and paid for on New York quotations) or a total value of £22 14s. 11d.

This ore was sent to the mill and yielded, after treatment for 18 hours in a 5 stamp battery, 6·70 ounces of bullion, worth £3 6s. 8d. per ounce, or £22 6s. 8d. and 2,325 lbs. of concentrates containing 15 per cent. moisture, leaving 1,977 lbs. net equivalent to 24½ per cent. of sulphides in the sample. The assay of the concentrates gave 1·76 ounces of gold and 10·37 ounces of silver per ton, or a total for the 1,977 lbs. of the above assay value, representing £9 3s. 5½d., or deducting smelting charges, £7 10s. 1½d. net.

To compare these results, the milling cost was at the rate of 3s. 6d. per ton; therefore the mill returned, after making all deductions, £29 2s. 8½d., estimated as follows:—Bullion, £22 6s. 8d.; concentrates, £7 10s. 1½d.; total, £29 16s. 9½d. Deducting milling cost at 3s. 6d. per ton 14s. 1d. equal £29 2s. 8½d.

At the smelter, the amount received, owing to the larger deductions and charges, reaches the smaller sum of £22 14s. 11d. Commercially, therefore, the mill ore paid the miner better than the smelting ore.

As a test of the mill-work the figures are as follows:—There was in the ore, 7·46 ounces of gold and 32·86 ounces of silver. There was extracted as bullion, 5·25 ounces of gold and 14 ounces of silver, and in the concentrates, 1·74 ounces of gold and 10·22 ounces of silver, or a total of 6·99 ounces of gold and 24·22 ounces of silver. Thus the mill, including the value of the concentrates, saved 93·8 per cent. of the gold and 74 per cent. of the silver.

The mill did not, however, complete the extraction of the gold and silver in the concentrates, so that it actually obtained, by amalgamation alone, 70·4 per cent. of the gold, and 42·6 per cent. of the silver.

This is said to be fairly representative of returns obtained on a large scale. Generally speaking, it has been found that the mill yields as many ounces of base bullion as there are ounces of pure gold found in the ore by fire-assay. The mill gold is 780 fine.

Considering that Gilpin County ore is probably one of the ores running highest in sulphides treated by amalgamation at the present day, the extraction of the stamp mills is certainly extremely good. That this is so, is due to the proper recognition of the necessity for altering modes of treatment in accordance with differences in the character of the ore treated—the first principle of successful milling.

The ore of the district has been described, and it may be added that in this locality ordinary panning, except with surface ores, will give no colours of gold, even with material which in the mill yields rich returns.

The *raison d'être* for the roomy mortars, slow drop, and deep discharge which characterize the Black Hawk mills are fully explained by Mr. Rickard. His views entirely agree with the writer's, expressed in a later part of this paper.

The absence of rock-breakers in the Gilpin County mills is largely due to their bad situation, which was chosen to utilize as far as possible the motive power of the creek. The position of the mill-buildings in fact (except at the expense of elevating the ore) prevents the erection of ore-bins and grizzleys, which are necessary adjuncts for running a stone-breaker economically.

Though the mills, crushing as they do very slowly, have not the same crying need for a rock-breaker as that which exists in a Californian or Australian mill, it is no doubt a defect; for apart from the improvement in the feeding which follows the introduction of a breaker, the irregular work of the sledge must tend largely to increase the strain on the mill machinery, as evidenced by the wear and tear of the shoes and dies which in this section is excessive.

On the score of regular and accurate feeding, the automatic machine is preferable to the average man, who cannot always resist the temptation of an occasional pipe or spell of rest. Their economy is most apparent of course where stamps crush fast, but even in a case like that of Gilpin County practice, an advantage may be shown in adopting them, notwithstanding that one man feeds 25 heads.

For 75 stamps, the cost of feeding comes to a total of £1,354 3s. 4d. per annum, while, on the other hand, if a mill of the kind were supplied with the most expensive of self-feeders, the cost of the additional plant would not exceed £834 6s. 8d.

Feeding machines are, however, of little use unless preceded by grizzleys, breakers, and ore-bins, and therefore recognizing the unfortunate position of the mill-buildings at Black Hawk (chosen in the days preceding the introduction of improved labour-saving appliances), however averse one may be to methods out of date, and machinery which is incomplete, one cannot say that, from a shareholder's or mill-man's point of view, present practice could be advantageously altered.

The Black Hawk mill-man has been trained in the best school, that of experience, supplemented by the necessities of keeping a close watch over the treatment of an ore subject to frequent changes in mineralogical con-

stitution. The competition for customs ores renders him in fact careful in the treatment of the stone, and keenly awake to any possible improvement of method promising ultimate economy.

The milling is recognized to be as important as the mining, and mills are not placed under the direction of men who are simply good miners, good chemists, or anything you will, but assuredly bad and inexperienced mill-men. In Australia it is not uncommon to consign a first-class battery to the tender mercies of an engine-driver who, in addition to tending the engines, is supposed to supervise the general mill work.

In Gilpin County, the management of the mill claims an equal or greater share with that of the mine. The needs of the district have produced men who are fully conversant with the bed-rock principles of gold milling, and such men are not too well paid, though earning more than the mine foremen.

Customs milling has had the beneficial effect (by rendering the mill owners anxious to gain the confidence of the public) of placing the right sort of men in charge, and by encouraging competition in doing good work has benefited the mill-men themselves. Gilpin County practice in fact leaves the impression of good work, intelligently and conscientiously done—two factors of the first importance to the mine owner and mining industry.

Colorado's production of gold appears to have been largest in 1886, when it is stated to have produced 4,450,000 dollars (£1,250,000) worth as against 3,883,859 dollars (£809,135) in 1889, whilst its silver output was valued at 23,757,751 dollars (£4,949,530) in 1889.

Practice in the Thames District, New Zealand.

This once famous mining district, also known by the Maori name of Hauraki, is situated in the north-eastern corner of New Zealand. Though the output has now dwindled to about 30,000 ounces per annum, this has been in its day one of the richest gold-fields of the world. In 1871, the output was 330,326 ounces valued at £1,188,728. The Caledonia mine in the first 12 months' operations produced 10 tons of gold and paid £600,000 in dividends. The maximum depth yet attained is 600 to 700 feet, and the veins have unfortunately proved far less rich in depth than near the surface. The development of the gold-field has been crippled by share-jobbing, the curse of many other Australasian camps. Few districts have had so brief but brilliant a record, and few perhaps have lost such a large proportion of the gold extracted from the mines. Milling is conducted under the difficulties presented by ores of a very complex

composition, but so far the efforts made to overcome them have been of a very elementary description. It is for this reason that the tailings-mills on the field are to-day amongst the most profitable undertakings.

Briefly stated, the method of milling consists in catching all the free gold by means quite unsuited to the character of the ore, and allowing the remainder to go to enrich the sea-beaches. The character of the ore and lode-formation in which it occurs, help partly to explain a state of things which calls for such severe criticism. The bulk of the gold comes from narrow veins and extremely rich pockets traversing a decomposed andesite. Such ore-bodies must necessarily be uncertain in behaviour and of limited extent. Like the deposits of Nagyag and Veraspotak in Transylvania, to which they have a striking resemblance (the country rock, the deposition of the ore, and the character of the gold specimens, as well as their alloyage with silver, being very similar), the pockets found on the Thames are occasionally of extraordinary richness. For instance, one lot of 2 tons 8 cwts. crushed 2½ ounces per pound, and a boulder of 2½ cwts. yielded 3,500 ounces. These crushings of small quantities of very rich ore pay the dividends, and the bulk of the output being of small value in proportion to the specimen ore, the former has been sacrificed to the latter.

The chief features of the milling are indicated by the subjoined table:—

Name of Mill.	Saxon.	Moanataeri.	Cambria.	Kuranui.	Comer.
Number of stamps	32	40	20	20	20
Weight of stamps (lbs.)	785	659	620	670	840
Number of drops per minute ...	72	66	76	70	63
Height of drop (inches)... ...	9	8	9	5½	6
Average depth of discharge (ins.)	2½	2	3	2¼	2½
Capacity per head (tons) ...	1·8	1·4	1·7	2·5	3·6
Capacity of mill (tons)	58	55	35	50	72
Description of screen		Punched	Russian	iron.	
Number of holes per square inch	148	170	180	160	160
Fineness of bullion (per 1,000) .	663	641	674	605	589
Percentage in retorting	42	40	40	45	48
Life of screens (days)	6	6	5	5½	5
Loss of mercury per ton of ore (dwts.)	14·5	15·2	—	—	—
Number of berdans	8	21	15	7	5
Number of other pans	3	4	—	—	—

No concentrates are obtained in any of these mills.

The Saxon mill it will be observed contains 32 stamps, with an extra single stamp kept for the treatment of specimen ore. The weight of the stamps, shoes and dies, and rate of drop are not the same, though the latter (subject to variations) averages 72 per minute. The depth of discharge is about 1 inch at the time of putting in new dies, increasing to

a maximum of 4 inches as they wear down. The height of drop is from 8 to 11 inches, depending on the hardness of the ore. The single stamp weighs 7 cwt. It is given a 7 inches drop, and a speed of 60 drops per minute. This specimen stamp is a curious feature of all the mills. The screen or grating used is of Russian iron, imported from Swansea. The life of a grating averages 6 days. The openings are round, punched with 148 holes per square inch. The loss of mercury is at the rate of a bottle (75 lbs.) per month, three bottles being kept in stock. No mercury is used in the mortar save for the specimen stamp. It is employed on the plates and in the ripples or wells, and in the pans. Owing to the flowering produced by the pans, the loss of mercury is excessive, viz., 14½ dwts. per ton of ore treated. The amalgam retorts about 42 per cent. The ore brought to the mill is discharged into stalls behind the batteries. The stone is there spalled and hand-fed. The ore varies in hardness according as the andesitic vein-filling is decomposed. The quartz itself is often saccharoidal. The shoes and dies of local manufacture are of white hæmatite cast-iron, the die differing from the shoe in being unchilled. The former is 10 inches in diameter and 4 inches deep, the latter 9½ inches in diameter and 10 inches high. The die is cast with a flanged footing to keep it in position. The mortar-boxes are faulty in design, being too roomy inside.

The pulp is discharged on amalgamating-tables 7 feet long and 4½ feet wide. These are in three divisions, of which the two upper ones only are copper-plated. The first length is 2½ feet, inclusive of a well 2½ inches wide. This well contains mercury. The next division is 18 inches long. The ripples (riffles) are four in number, one only (that already mentioned) containing mercury. The other three (2 inches deep) are blind-ripples. The gold saving is effected by the plates and wells, and indirectly by blanket-strakes whose residues are treated in pans. The mortar-box is merely a crusher, not an amalgamating appliance.

The plates of Muntz metal are roughly cleaned every 4 hours. The wells are of little assistance, and are really unsuitable to ores containing a notable percentage of sulphides. They tend also to conceal the careless use of mercury.* The surface of the bath of mercury is constantly coated with a scum of sulphides, which prevents contact with any gold passing over it. The wells are skimmed with a cloth every 4 hours, and

* With plates immediately in front of the battery-screens a check is afforded of the work inside, and of the proper proportioning of the quicksilver feed or the reverse, while the well hides the fact, for a time, of a too liberal use of mercury or otherwise.

considered as a combined silver and gold ore, containing from ½ to 10 per cent. of sulphides with an average of 2 to 3 per cent.; it approaches the boundary-line dividing a free-milling from a refractory ore.

Reviewing the chief characteristics of the milling, we see that the feeding is done by hand and is very rough, being left to boys, instead of employing trained men. The former shirk breaking big pieces of rock, preferring to throw them into the feed-opening, where, if they stick, they are belted-in with a few blows of a sledge-hammer. The result of the absence of rock-breakers and automatic feeders in lieu of this bad hand-feeding is seen in the excessive wear of the shoes and dies, averaging 14·5 ounces for the shoe and 7·5 ounces for the die. The feeding is also too high, the batteries being kept choked with ore, which reduces their efficiency.*

The mortar-boxes are of the same pattern, whether employed for rapidly crushing soft material or the slower treatment of average ore. As no amalgamation is done inside, they are too wide. When the mortar is merely a pulverizer, the pulp should be expelled as soon as possible; too roomy a box promotes dead-stamping, keeping in ore, after it has been stamped fine enough to escape under ordinary circumstances. When amalgamation takes place inside, the case is different, but at the Thames, it would seem expedient to use narrower mortars.

The destruction of the gratings is particularly rapid, owing to the unusual quantity of proto-sulphates of iron, copper, manganese, and alumina present; and with wet mill-stuff which has lain long in the stopes, or on the surface, the action is very marked. As is usual in Colonial mills, the screens are fixed vertical (instead of having a slight forward inclination at the top), which tends to wear out the lower portion, faster than the upper, as well as to diminish the discharging capacity of the screen-surface; as the ore particles are not necessarily obliged to strike an opening, to escape. The water shot against an inclined screen from the inside, has also the advantage no doubt of carrying a certain quantity of material out, in running down the inclined screen-surface, unless burred screens are used.

* An experienced millman can tell by the sound of his stamps if they are running properly. Any particular stamp can be tested by holding the stem lightly between the fingers, about 18 inches above the mortar-box, and allowing the hand to be raised and lowered, by the rise and fall of the stamp. If the stamp is overfed it will fall with a dull short stroke; if underfed, with a long vibrating, ringing blow (like a hammer on an anvil); if properly fed, with the sharp well-defined crack you ought to expect.

The mercury wells only confirm the general experience that with ores containing an appreciable quantity of sulphides, they are of little practical value, not being even of a type (like those of Clunes), which compels the pulp to pass through the mercury-bath, so far as that end is capable of attainment. The blind-ripples occupy an amount of time which appears quite out of proportion to the quantity of sulphides and heavy sand which they collect.

The blankets are washed at too long intervals at most of the mills running on company ore, and therefore, tributers (who understand this) generally attend to that part of the business themselves, washing the blankets and skimming the wells every half hour. The blankets, which are 2 yards wide cost 12s. per yard; they last three months.

The substitution of a drag, or pair of drags, certainly is an improvement on the ball, formerly used in the berdans, which wallowing about in the mercury and amalgam (at the bottom of the pan), presented extra chances of flowering them. The drag being fixed to the side of the pan keeps the grinding and amalgamation to some extent apart, but more or less mercury is carried round constantly with the sulphides by centrifugal action, hence the evil is but partly mitigated.

Systematic attempts at proper concentration by modern methods do not appear to have been made, in consequence of which a Newberry-Vautin chlorination plant erected at the Thames had to shut down for want of being able to obtain a regular supply of concentrates. The mill results seem to show that only that part of the gold which is readily amalgamated is caught, while the silver contents escape.

The silver in the bullion is not in fact due to the amalgamation of the silver minerals in the ore, since the proportion of silver to gold in the bullion corresponds with the native gold, which like that of Transylvania, is of very low caratage.

On the most favourable estimate but 50 per cent. of the gold is saved, leaving out of account the silver. Much of the gold and nearly all the silver is carried away with the slimes, which being carried out along the foreshore have produced an accumulation of tailings, estimated to amount to at least a million tons, carrying half an ounce of bullion per ton.

That this is not an exaggerated statement is proved by the success of the tailings-mills, which pay well.

The largest of these plants contain twelve Watson and Denny pans. The tailings are elevated and conveyed to them simply and effectively by a

small hydraulic elevator, the jet being ⅝ inch in diameter, with a 2½ inches pressure pipe, and 3 inches elevator or discharge-pipe. The water used is under a pressure of 60 lbs. per square inch. The launder from the upper end of the elevator-pipe conveys the tailings to wide strakes, where the poor slime is washed away, and the rough stones are picked out, before feeding the residual material to the pans. The cost of this treatment, including insurance, interest on plant, wear and tear, etc., amounts to 3s. 6d. per ton.

Mr. Rickard points out that while blankets, followed by pans, form a process which is quite ineffectual as regards saving the silver contents of the ore, it is also badly suited to extraction of any free-gold remaining in the pulp, after its passage over the plates.

The grinding action of the pans upon the sulphides forms slimes, which sicken the mercury, cause its direct loss, and further spoil its power of amalgamating.

The ore is both silver and gold-bearing. The former metal is chiefly associated with the sulphides, the latter is mostly in the quartz, while both minerals occur combined as tellurides, etc. Some separation is therefore needed between the silver and the gold-bearing portions of the ore. He (Mr. Rickard) suggests, therefore, that from plates the pulp should pass direct to concentrators, and thence to pans. The concentrators would separate out the silver-bearing minerals and some of the combined gold, and the pulp, freed from the sulphides, would go to the pans, which would complete the extraction of any free-gold remaining.

This combination process would obviously be an improvement on present methods, without involving much expense.

The work might be further lightened and improved upon by introducing classifiers of the Spilzlütte type, between the amalgamating-tables and the concentrating-machines. The handling of the concentrates would then be by an auxiliary process, and would not interfere with the present amalgamation upon the tables.

The use of Muntz metal in place of copper, has been referred to elsewhere, and its first introduction for the purpose took place in this district in 1875. Owing to a scarcity of copper, the local ironmongers, who imported it for sheathing ships' bottoms, sold it as a substitute. Its use rapidly spread, though the sheets locally used are too thin for the purpose, being of the thickness known as No. 18. They last, however, from three to five years.

Muntz metal as applied to amalgamation has been found to possess the

following characteristics :—It does not absorb amalgam like copper, the latter requiring to become thoroughly coated before the plates will work well.

Muntz metal has very little absorbing power over the mercury, and the amalgamation is relatively to copper, very superficial. Hence the amalgam formed on the Muntz metal is more readily detached, facilitating the clean-up. A simple rubber is always sufficient, so that the use of a steel scraper is avoided.

Test crushings are more reliable in consequence, since if the copper-plates are scraped too close before putting through a fresh lot of ore, they have not a fair chance to amalgamate, while if amalgam be left on, gold is obtained which does not belong to the stone on trial. It is not so with Muntz metal, which can be readily deprived of all its previous gain of gold-amalgam without impairing its efficiency, and is therefore specially adapted to customs mills.

On the other hand, for rich ore, Muntz metal is not to be recommended, as there is insufficient body in it, that is to say it is sooner saturated with gold-amalgam than copper. In the same way silver-plated copper, will carry more amalgam, than when the plain metal is used. This disadvantage is partly to be overcome by frequent cleaning-up. When ores contain minerals injurious to the mercury-surface, Muntz metal is preferable.

Sickening is prevented in the presence of base metals by the action no doubt of the zinc, forming one of the components of the alloy, which liberates hydrogen, and so exerts a powerful reducing effect. Muntz metal plates are easier therefore to keep in order than copper. They are hardly ever affected by sickening, and verdigris (caused by the presence of impurities in the ore and battery water) is remarkable for its absence.

Formerly at the Saxon mill, a 7 lbs. jar of potassium cyanide, costing 23s., was needed monthly for dressing the plates. After introducing Muntz metal, half a bottle of sulphuric acid (costing 3s. 4d.) sufficed for the same time. With highly acid ores (heaps of waste and old mullock-tips), copper, however, is to be preferred, as a scum is formed on the Muntz metal, while the free acid in the stone tends to keep the copper clean. In both cases it must be understood, however, that the amalgamation is interfered with.

At the Cambria, a customs mill, both varieties of plates are used: Muntz metal for the top, and copper for the bottom of the table, so as to meet the requirements of different kinds of ore. The result of experience in the Thames mills has been therefore to recommend Muntz metal for amalgamating plates where poor ore is being crushed, also in custom

milling, and where the ore is charged with minerals which injuriously affect the mercury. For material containing acid waters or very rich ore, unaccompanied by a large proportion of sulphides, copper-plates are preferable. In general, Muntz is the cheaper metal of the two, it lasts longer, facilitates a rapid and easy clean-up, and requires less attention. These points should recommend it for customs mills.

In dressing new Muntz metal plates the following are the steps to be taken:—Rub the surface of the plate with fine clean sand to get it mechanically clean, then wash it with a weak (1 to 6) solution of sulphuric acid to make it chemically clean. Then start to rub in a little mercury; rubbing in one place till it bites, that is a spot begins to amalgamate. Give a circular movement to the flannel or mop; once started, the amalgamation spreads in ever-widening circles.

There is something generally to be learnt from acquaintance with each new mill and camp, each district has a lesson to give and every mill offers some suggestion.

Practice at Clunes, Victoria.

Clunes is rendered famous as the locality where Mr. J. W. Esmond discovered the first gold found in the colony, on June 29th, 1851; though not equal in importance as a mining centre to either Ballarat or Bendigo, it has done most useful work in the development of the mining and milling practices of the Colonies.

The history of the old Port Phillip batteries of the Port Phillip and Colonial Company, has had an important effect on colonial quartz reefing; a model which has left its impress on the system in vogue at the present day. At the date when crushing first commenced in May, 1857, the treatment of gold-quartz was a problem entirely unsolved, and the Port Phillip mill laid down the basis of modern Colonial ideas on the subject. While assays proved the loss in the tailings in 1861 to amount to 6 dwts. 1 grain per ton, by numerous changes (suggested by careful experiments) this loss was decreased, till in 1870, it had been gradually reduced to 17 grains per ton. It should be remarked, however, that the average grade of the ore appears to have also altered, the yield averaging 12 dwts. 20 grains in 1861, as against 5 dwts. 17 grains in 1870.

In 1864, the plant was increased to 80 heads, and the first buddles were placed in position in 1865. The first rock-breaker was then introduced. The mine paid its highest dividends (£48,271 17s. 6d.) in 1867, on ore valued at 8 dwts. 23 grains per ton, with a loss of 2 dwts. 7 grains in the tailings. While from 1857 to 1881, it produced 1,204,908 tons of quartz, which yielded gold to the value of £1,946,989, out of which £481,455 were distributed in dividends.

The ore from the mine passes through the rock-breakers, preceded by sizing-bars (grizzleys), before entering the mill, which was built in different sections, at various periods.

No. of Heads.		Weight of Heads or Shoes. Cwts.		Date of Erection.
20	...	2½	...	1857
24	...	2½	...	1858–1859
12	...	2½	...	1860
24	...	3¾	...	1864

There are four stamps to each box. The stamp-heads and shoes are square. The mortars have a back-and-front discharge. The daily crushing capacity is at the rate of 2 tons 12 cwts. for the light stamps, and 3 tons 12 cwts. for the heavier ones. The speed is 82 drops per minute, and the height of drop is 8 inches. The issue or depth of discharge is maintained as far as possible at 4½ inches. The grating is of copper, pierced with 81 round holes per square inch.

The pyrites concentrated on the Munday buddles have amounted to ¾ per cent. of the ore crushed. Its average contents have been 4 ounces 1 dwt. 14 grains per ton. The bullion is 965 fine. The retorting percentage has averaged 38.

The business of the mill has always been carried out in a most systematic manner. The following statement of product is from the mill records for the four weeks ending May 21st, 1873:—

Where Amalgam was Produced.		Oz.	Dwts.		Retorted. Ozs.	Dwts.		Per Cent. of Total.
Mortar-box (bed)	...	1,466	0	...	673	11	...	59·05
Wells	...	708	3	...	249	12	...	21·87
Blankets... ...	...	408	2	...	121	12	...	10·66
Mills	...	383	0	...	96	7	...	8·45
Total	...	2,965	5	...	1,141	2	...	

Other statistics kept were as follows:—Number of stamps, 80; tons crushed, 5,023; hours worked, 518 or 21·58 days. Average duty per stamp, 2·9 tons; yield per ton, 4 dwts. 10·12 grains; loss in tailings per ton, 20·16 grains; contents per ton, 5 dwts. 6·28 grains.

The amalgam coming from the mortar-box retorts 46 per cent.; from the wells, 35 per cent.; from the blankets, 30 per cent.; from the Chilian mill, 25 per cent. Of the total product obtained by direct amalgamation more than half came from the mortar-box, indicating the free-milling character of the ore. Of the total, 80 per cent. went no farther than the wells immediately outside the box. The above yield, deducting loss, represents an extraction of 84 per cent.

The batteries of the Port Phillip works are now idle, but the milling practice they inaugurated is seen reproduced in the newer mills of the South Clunes, and Dixon's North Clunes works.

The following table illustrates their different features. It may be mentioned that prior to 1865, the ore was calcined to render it more easily broken. This practice has not yet altogether died a well-merited death in Victoria and New South Wales:—

Name of Mill.	Port Phillip.	South Clunes United.	Dixon's North Clunes.
Number of stamps	56, 24	60	30
Weight of stamps (lbs.)	728, 896	896	896
Drops per minute	82	80	80
Height of drop (inches)	8	8	8
Depth of discharge (inches)... ...	$4\frac{1}{2}$	$4\frac{1}{2}$	7
Capacity per stamp (tons)	3	$2\frac{1}{2}$	$3\frac{1}{2}$
Total capacity (tons)...	240	150	100
Grating...		Copper-plate.	
Holes per square inch	81	100	180
Concentrates (per cent.)	$\frac{3}{4}$	$\frac{3}{8}$	3
Contents of concentrates	4 ozs. 1 dwt.	3 ozs. 5 dwts.	3 ozs.
Bullion fineness (per 1,000)... ...	970	968	978
Loss of mercury per ton (grains) ...	$5\frac{3}{4}$	$5\frac{1}{2}$	$5\frac{1}{2}$
Wear of grating (days)	30	25	?
Water per stamp per minute (gallons)	6	8	10
Retort (per cent.)	38	42	40

At the South Clunes United mill, as the die wears down, sand is packed underneath, and when about 2 inches have worn away, a sectional false-bottom is placed underneath; in this way the depth of discharge is kept fairly constant at $4\frac{1}{2}$ inches.* Each section of the false-bottom consists of a plain iron casting of sufficient length to serve for two dies, the centre die being supported by a section of half the length of the others. The rate of crushing averages 2·4 tons per 24 hours.

The screen is of copper-plate, weighing $1\frac{1}{2}$ lbs. per square foot, and is perforated with 100 holes per square inch. The average wear is about 25 days, working full time. Iron punched gratings scarcely lasted a week. The concentrates have increased with the depth of the workings from $\frac{3}{4}$ per cent. to 1 per cent. The concentrates usually carry 3 ounces of gold. Lately, however, they have become poorer, 28,820 tons of ore yielding 178 tons 19 cwts. 3 qrs. of pyrites worth £560 12s. 8d. The percentage of gold in the amalgam varies from 36 to 45.

The mill-stuff is discharged into ore-bins, but the ore is fed by self-

* In California, wooden blocks, set so as to raise the screen framing, serve the same purpose.

feeders, of simple design, to the boxes, which have a front-and-back discharge.* The battery pulp passes through wells and then over blankets.

The blanket washings are treated in revolving barrels with mercury. The tailings go to Cornish buddles supplemented by ties outside the mill. Tramming the ore one-third of a mile to the mill and breaking it, costs 8d. per ton.

The feeder before-mentioned, is somewhat similar to an arrangement common in German stamp-batteries, consisting of a rod which has a round iron disc keyed to its upper end, projecting below a false or extra tappet attached to the middle stamp of a battery of five heads. The shoe (fixed to the lower end of this rod) gives a shock to the shoot leading from the ore-bin to the battery-pocket. Whenever the ore inside the box has worked down low enough for the false tappet to strike the disc of the rod, a fresh quantity of stone is thrown into the mortar.

The discs are keyed on. The order of drop of the heads is 5, 3, 4, 2, and 1. The shoes are of cast-iron, 10 inches in diameter and 10 inches high. The dies are hexagonal, of wrought-iron,† with a diameter of 10 inches and depth of 6 inches. New shoes weigh 196 lbs., new dies 140 lbs. A shoe will crush 90 tons and a die 420 tons before it is worn out Cast-iron shoes cost 12s. 6d. per cwt. and wrought-iron dies 11s. 6d. per cwt. delivered at the mill.

The gratings are vertical and covered by a splash-box which slopes forward. The front grating-frame is 5 feet by 13 inches, while the back one is 5 feet by 12 inches. The pulp discharged from the back, is led round to the front of the box, by a launder.

The whole of the battery discharge falls on to an iron plate in front of the lip of the mortar, which is $\frac{3}{16}$ inch thick, punched with $\frac{5}{16}$ inch holes, drilled at the four corners of a square inch, and is called the distributor. Its function is to spread the ore over the whole width of the tables and wells, and to catch any of the coarse stone in the battery-bottoms in case of a screen happening to break accidentally at the bottom, which is liable to occur with iron screens with a low discharge, but is generally an indication of over-feeding. In cases of this sort, where amalgamated plates are used under the lip of the box, it may save amalgam from being scraped off and lost, and as pointed out elsewhere it has a tendency to form

* The use of a double-discharge is limited to ores which cannot be amalgamated in the battery with advantage. This is a case in point, another one is with a high sulphide ore, especially if it contains brittle sulphides, which from over stamping are liable to be slimed.

† In America, steel shoes and iron dies are used in some mills, it being found that the iron die wears more evenly than a steel one would do.

thick rough bosses and ridges of amalgam, for a width of several inches, where the streams of water fall on the copper-plates.

At the South Clunes mill, the pulp from the distributor is spread over a plain wooden apron 20 inches wide and 2 inches thick which further aids its distribution. Two wells succeed this, which are guarded from theft by a wooden grating kept under padlock. The first well has a drop of 10 inches and a depth of 4 inches. It holds 50 lbs. of mercury, and the pulp in passing through it, is forced under a narrow upright board (running lengthways along the well close to its edge, on the side nearest the battery) in contact with the quicksilver. The second well, which follows immediately after, has a drop of 8 inches, is 4 inches deep, and also holds 50 lbs. of mercury. These wells, including the lip, are of cast-iron, and have a curved inside contour. They are sunk into the wood of the frame holding them. Iron wells appear to have a tendency to keep the mercury quick and lively. At Clunes they have an inside diameter of 3 inches, and are placed so as to have a slight slope to one end, where a tap-hole facilitates the removal of the mercury at cleaning-up time.

The pulp passes from the wells to the blanket tables, which have a width that takes in two batteries of five heads each. This width is sub-divided by seven partitions, 18 inches wide and 12 feet long. The grade is ¾ inch per foot. Then follow five circular improved Cornish buddles (Munday), and finally the tailings pass over ties outside the building. These last have a length of 20 feet and a fall of 1 inch per foot. The gold saving is effected by the mortar-box and wells, and indirectly by the blankets, buddles, and ties. No mercury is employed in the box, which the use of copper-gratings would in itself prevent, while the very free character of the gold, does not necessitate its use at this stage of the treatment. The mortar-box is roomy, and gives the gold an opportunity to separate from the pulp by the action of gravity alone. The interior length is 58 inches, interior width 16 inches, width between dies 1 inch, with an extra inch between the side dies and the ends of the box. Distance from dies to back of mortar 4 inches, from dies to screen 8 inches, and between centres of dies 11 inches.

In cleaning-up, the gratings are removed, and the material inside and around the dies is shovelled into buckets and passed over a strong wire riddle* 2 feet in diameter and No. 4 mesh. One of these lasts a year. The roughs from this operation go back to the mortar-box to reset the dies before restarting, 1½ to 2 buckets being obtained at each fort-

* In Queensland, they are generally run through a tom or rocker, and the pyrites caught in the riffles is ground in pans.

nightly clean-up. The fines are sifted into a blanket-tub, and then introduced into an amalgamating-barrel. There are five such barrels in the mill, with a capacity of 54 gallons each. They make 16 revolutions per minute and are worked from 8 to 12 hours, 10 hours being the average time. The water is used cold; 75 lbs. of mercury are added to each charge with a bucket full of wood-ashes. When the amalgamation is finished, the contents of the barrel are discharged into a wooden tank, and passing through a perforated plate, flow over three drop-wells, with drops of 12 inches, 9 inches, and 6 inches respectively. Most of the amalgam is caught in the top well, the third is merely a safeguard. This disposes of the treatment of the residues.

The battery-wells are cleaned up once a week and the amalgam squeezed. The skimmings taken from the surface of the wells (largely consisting of heavy pyrites) are ground and amalgamated in three 3 feet berdans. The blankets are washed in tubs, the first row every hour, the second every alternate hour, and the third every third hour. With rich ore the washing is done more frequently. The blanketings caught, are treated in amalgamating barrels* in much the same way as the mortar-box residues. The material collected by the ties (straight troughs, in which heavy pyrites, etc., is settled by gravity), are also treated in the barrel. The tailings from all the barrels go to buddles. The concentrates thus obtained are roasted in a reverberatory furnace, then ground in a Chilian mill with the addition of mercury, by which the gold is amalgamated. The total yield of the mill in one month, crushing 2,973 tons of stone, which yielded 981 ounces 19 dwts. 12 grains of gold was thus distributed:—

	Amalgam. Ozs.	Amalgam. Dwts.	Bar-gold. Ozs.	Bar-gold. Dwts.	Retort Percentage.
Mortars	955	5			
Wells	644	19	840	19	36 to 48
Blankets (by the barrels) ...	364	15			
Skimmings (by the berdans) ...	167	14	53	2	32
Tailings (by the ties and barrels)	24	10	7	5	30
Concentrates (pyrites, 17 tons)	310	4	80	13	26

Neglecting the concentrates and tailings, of the total amalgam caught, the percentage is therefore thus distributed:—Mortars, 44·8 per cent.; wells, 30·2 per cent.; blankets, 17·1 per cent.; skimmings, 7·9 per cent. The loss of mercury for the past seven years has averaged 5½ grains per ton of ore crushed. Occasionally the loss has risen to 1½ ounces per ton of ore, due to formation of copper-amalgam, which like lead-amalgam floats on

* In California, an Attwood amalgamator sometimes serves for the amalgamation of the blanketings.

the mercury, and is readily carried off with the tailings. The presence of the copper cannot be attributed to the copper gratings, but to particles of native copper in the ore. At one time, 80 ounces of copper were collected in one month from the skimmings of the wells. The total consumption of mercury (inclusive of treatment of pyrites in Chilian mills) during eleven months from July 1st, 1891, to June 30th, 1892, amounted to 3,302 lbs., when crushing 309,400 tons of ore, equivalent to a loss of 3 dwts. per ton of ore.

Up to the year 1879, according to information furnished by Mr. Hewitson, the manager, the gratings used were imported from England, being made of copper $\frac{1}{16}$ inch thick, drilled with 81 holes per square inch. When in full work the imported grating lasted twelve months, 2,200 tons of ore passing through each grating. At the Port Phillip mill, owing to its smaller area, the life of a grating reached 1½ years. The protective tariff caused the imported grating to become too expensive, and one of domestic manufacture took its place. This wore for less than half the time, but six times as long as ordinary punched iron. The experience with the present lighter type of copper grating has been very good. During the last seven years, 258 gratings have been used up. Their cost was £197 6s., and during that time 181,792 tons were crushed, or at the rate of 355 (long) tons during the life of a grating. It was found that ordinary punched Russian iron lasted only one quarter the time of the new style of grating. Baize is used for the blanket strakes; the cost of this item in one year was £49 7s. 2d. During the same period the wages at the mill amounted to £1,306 4s. 9d., treating 28,820 tons of ore, or 10½d. per ton.

The total cost of milling, including supplies, wear and tear, treatment of pyrites, etc., amounted to 2s. 3d. At Dixon's North Clunes mill the front grating is copper with 180 holes per square inch, while the back grating is brass wire with 230 holes to 240 holes per square inch. They have 6 patent Munday buddles with iron scrapers, 2 to each 10 stamps. The pyrites is washed and treated in a Chilian mill at a cost of £1 16s. 11d. per ton. The roasting of 85 tons 1 cwt. cost £89 6s. 7d., and grinding £67 15s. 11d., or a total cost of £157 2s. 6d.

The smaller capacity of South Clunes United mill, as compared with the other two referred to in the table, may be accounted for by the absence of a rock-breaker.

The finer gratings of the Dixon's North Clunes mill are offset by the less depth of discharge of the other batteries. The retort percentage of the North Clunes mill, notwithstanding that the gold in the ore is of a coarser

nature, is not quite so high as that of the South Clune's, owing no doubt to the finer size of grating. The large quantity of water used in the mills of this district is accounted for by the double-discharge of the mortars and the use of very wide blanket-tables.

The loss of mercury is exceedingly low: 5½ grains of mercury per ton being probably one of the smallest on record,* this may be attributed to the avoidance of the chief cause of loss in an ordinary mill, viz.: flowering in the battery, which cannot of course happen here.

The ore treated in these mills is broken from quartz-veins, traversing slate and sandstone-beds. When sent to the mill, the quartz is accompanied by a small admixture of country rock. The quartz is white, often honey-combed, and sometimes saccharoidal. The gold is coarse, often of very high caratage, frequently visible to the naked eye, and arranged for the most part along the faces of small fractures, or seams in the quartz; a blow therefore tends readily to detach it. Occasionally the percentage of mullock (waste rock) increases considerably, and the gold is accompanied by pyrites, chiefly composed of arsenic and iron sulphides, or occurs in a matrix consisting of slate and quartz intermixed.

The Port Phillip and Colonial mill-book shows that the proportion of the total yield of gold coming from the mortars and wells steadily declined from 1868 (when it stood at 87·03 per cent.) to 1879 (when it stood at 68·49 per cent.). On the other hand, however, the yield from the blankets and concentrates increased correspondingly. The explanation lies in the fact that as the mine workings reached a greater depth, the ore, by the steady increase of the pyrites it contained, became less free-milling.

This reasoning is confirmed by the returns, for while in 1866, the yield of concentrates amounted to 268 tons, averaging 2 ounces 19 dwts. 4 grains from the crushing of 59,578 tons; in 1879, the pyrites amounted to 421 tons, averaging 4 ounces 15 dwts. 20 grains, resulting from the treatment of 56,766 tons. In 1870 the use of blankets was discontinued, but in 1873 it was resumed; in the interval the yield from the Chilian mill increasd considerably. In 1865, the ore yielded 7 dwts. 13¾ grains per ton; of which amount the boxes yielded 63·60 per cent.; the wells, 22·09 per cent.; blankets, 10·55 per cent.; mills, 3·76 per cent.; and mills and blankets, 14·31 per cent. In 1872, the ore yielded 4 dwts. 17¾ grains per ton; of which amount the boxes yielded 64·48 per cent.; the wells, 21·60 per cent.; the blankets, 1·06 per cent.; the mills, 12·86

* The record of greatest waste, it is stated, occurred at a mill in the Thames district, where 1 ton of mercury was used up in two weeks by a mill of 20 heads.

per cent.; and the mills and blankets, 13·92 per cent. In 1879, the ore yielded 8 dwts. 19¾ grains per ton; of which amount the boxes yielded 57·99 per cent.; the wells, 10·50 per cent.; blankets, 12·84 per cent.; mills, 18·67 per cent.; and mills and blankets, 31·51 per cent.

To consider the method in practice, it will be admitted that the use of costly chemicals in milling is as far as possible to be avoided. Mercury is generally a large item, and since 55 to 65 per cent. of the gold can be arrested in the box, without its use; the practice of the district in dispensing with it in the box, appears correct and advantageous. Under the stamps, it is liable to be flowered, *i.e.*, broken up into minute globules, which, collecting impurities, become covered with a film which makes them refuse to coalesce, causing them to be carried away on the surface of the water. With this loss of mercury there must also be a loss of gold, particles of which have entered into amalgamation with the escaping globules.

The absence of amalgamating-plates is remarkable, but in view of the character of the ore, Mr. Rickard considers it correct. Wells, as he states, are excellent-gold savers for ore of this type, in which the metal is both free and coarse. He points out as their advantages that they require less attention, their first cost is less than that of plates, and they are less affected by the occasional presence of minerals in the ore, injurious to amalgamation. Blankets, when intelligently used, are among the best of the simple contrivances known to mill-men, given as they are at Clunes plenty of width. At South Clunes there is a clear blanket space of 10½ feet. Ordinarily the slope of the blanket-tables would be 1¼ inches to 1½ inches per foot; but at Clunes, owing to the use of plenty of water due to the double-discharge, they have a pitch of only ¾ inch per foot. This is in itself an important factor, apt to be overlooked.

The after-treatment in the barrels may seem crude, but practice has shown it to be effective. The bad custom of putting pieces of iron into the barrel, with the idea of mixing and grinding-up the pulp, is here avoided, saving a large loss in flowered mercury. The means taken to keep the discharging depth of the mortar constant, is a factor of importance in the method pursued, which does credit to the practice of the district. The self-feeders do their work well, and though not perfect, are a great improvement on the bad and irregular hand-feeding which prevails in the majority of Colonial mills. The concentrating machinery may with reason be considered somewhat out of date, but the modified Cornish buddles in use, are doing excellent work. The use of the double-discharge mortar increases the crushing capacity of the mills, but also requires a much increased supply of water.

Speaking generally, the treatment the ore undergoes is remarkable, most of all on account of its simplicity, but so is the ore; and in this way the local practice carries out the first postulate of intelligent milling, viz., that the treatment should be varied according to the character of the ore to be dealt with. After a careful examination of the ore mined at Clunes, and of the milling it is subjected to, it is possible only to speak in words of commendation. To a mill-man it is almost solitary among the gold-mining districts of the Colonies, in being a quartz-milling centre which does not leave a feeling of dissatisfaction, and an impression of dissapointment on the visitor. You may visit mills in the most distant parts of Australia, and almost without exception, whenever you find good intelligent milling (and that does not happen often enough to be monotonous), the knowledge and experience of the individual in charge, have been obtained at Clunes.

The Port Phillip mill was the first to introduce the system of taking daily assays as a check on the work done in the mill.* In this respect the Clunes mill is still unfortunately a striking exception. In another department this mill was also a solitary pioneer, the first rock-breaker being introduced by the Port Phillip in 1865. Yet in Victoria to-day, there are only twelve rock-breakers!

Mr. Rickard expresses the belief that the work done by the Port Phillip and Colonial Company's mill, has been of more wide-reaching usefulness and more permanent benefit to the mining industry of Australia and New Zealand, than that of any other company which has gone into operation since the days of the discovery of gold, and records his conviction of the debt which quartz-milling in the colonies owes to its manager, Mr. R. H. Bland, who started its operations in 1856, conducted the numerous and valuable experiments which did so much to establish the correct basis of milling practice, and to-day still assists the industry by his sterling good sense.

* Mr. Rickard mentions as another instance, the mill of the Harrietville Gold Mining Co., Ld.; and it was also done at the Disraeli mill in Queensland, when under the writer's charge.

(*To be continued.*)

The following paper on "Mining Explosives: Their Definition as Authorized under the Explosives Act, 1875," by Mr. A. C. Kayll, was taken as read:—

MINING EXPLOSIVES: THEIR DEFINITION AS AUTHORIZED UNDER THE EXPLOSIVES ACT (1875).

By A. C. KAYLL.

The Explosives Act, 1875 (38 Vict., c. 17), came into operation on January 1st, 1876. Briefly stated, the Act requires that all factories, stores, and explosives shall be licensed, and consequently these come under Government supervision.

The term explosive is defined as follows:—

"1. Means gunpowder, nitroglycerine, dynamite, gun-cotton, blasting-powders, fulminate of mercury or other metals, coloured fires and every other substance, whether similar to those above-mentioned or not, used or manufactured with a view to produce a practical effect by explosive or a pyrotechnic effect; and

"2. Includes fog-signals, fireworks, fuzes, rockets, percussion-caps, detonators, cartridges, ammunition of all descriptions, and every adaptation or preparation of an explosive as above defined."

Explosives are classed by Orders in Council as follows:—

Class 1. Gunpowder.	Class 6. Ammunition:
„ 2. Nitrate mixtures.	Division 1.
„ 3. Nitro-compounds:	Division 2.
Division 1.	Division 3.
Division 2.	„ 7. Fireworks:
„ 4. Chlorate mixtures.	Division 1.
„ 5. Fulminate.	Division 2.

Class 1.—Gunpowder is not included in this paper as its component parts are so well known.

Class 2.—Nitrate mixtures, other than gunpowder, such as safety blasting-powder, fortis explosive, etc.

Class 3, Division 1.—Nitro-compounds, containing nitroglycerine, such as dynamite, gelignite, stonite, ardeer powder, carbonite, etc.

Division 2.—Nitro-compounds, *not* containing nitroglycerine, such as gun-cotton, tonite, ammonite, roburite, schultze gunpowder, etc.

Class 4.—Chlorate mixtures, containing (especially) chlorate of potassium, such as asphaline. All chlorate mixtures are liable to spontaneous ignition, and are extremely sensitive to friction and percussion, hence, with the exception of asphaline, no chlorate mixture has been authorized in this country.

It is interesting to follow the history of dynamite during the past few years. In 1876, dynamites Nos. 1 and 2 were the only nitroglycerine compounds in use for mining purposes; No. 2 is little used in this country, and its definition remains the same up to the present time.

Up to 1886, other varieties were added, such as E.C. dynamite, dynamite 1 S., dynamite 1 S.B., but in that year the Nobel Dynamite Trust Co., Limited, acquired the shares of certain explosive companies, which led to a new and more comprehensive definition of dynamite No. 1, embracing the varieties known as 1 S., E.C., and No. 1 S.B.

In 1876, a new and important nitroglycerine and nitro-cotton compound was licensed under the name of blasting-gelatine, which in 1880, extended to four varieties, viz., blasting-gelatine Nos. 1, 2, 3, and 4. In 1883, the varieties known as Nos. 3 and 4 were removed from the list, and reappeared in the following year under the name of gelatine-dynamite Nos. 1 and 2. In 1886, another variety of this last No. 2 appeared under the name of gelignite.

These gelatinized compounds have almost entirely superseded the use of dynamite. The advantages of these compounds in mining are many: their being unaffected by water, their plastic nature, and their being more cleanly to use, are among the most important. On the other hand, these explosives are liable to exude a thin gelatine, which is liquid at ordinary temperatures, and when frozen they are very sensitive to a blow; the reverse holds good with dynamite.

With regard to the new class of explosives containing other nitro-compounds mixed with nitrates, such as ammonite, bellite, roburite, securite, etc., their less sensitiveness to percussion and friction while giving them the advantage of greater safety, exposes them to miss-fires, which become more frequent as the compounds age and absorb moisture.

With reference to the addition of ammonium salts to nitro-compounds, Dr. Dupré says in his report of 1890 that, while the addition of ammonium salts to dinitro-benzole has been sanctioned, the addition of ammonium salts, other than the carbonate, to explosives containing gun-cotton or nitroglycerine, has always been reported against. The assigned reason being that all ammonium salts, especially when exposed alternately to

moist and dry air at slightly elevated temperatures, lose traces of ammonia and become acid. Now, nitro-compounds, like dinitro-benzole, are little, if at all, affected by traces of acid, and under such circumstances show no tendency to spontaneous decomposition which might lead to ignition or explosion. Nitro-compounds, like gun-cotton and nitroglycerine (more strictly speaking nitric ethers), on the other hand, are seriously affected by traces even of acids, especially strong mineral acids, and decomposition once started goes on and ultimately leads to total decomposition, which may end in ignition or explosion. Hence ammonium salts exert no dangerous action on true nitro-compounds, but may fatally affect the stability of nitric ethers like gun-cotton and nitroglycerine.

It should be clearly understood that all the explosives mentioned in the following list are not necessarily manufactured, and, as a matter of fact, many of them exist only on paper.

IMPORTATION.

The amount of dynamite imported prior to 1881 was inconsiderable. (The import trade became established in 1881 after the expiration of Nobel's English dynamite patents in March of that year).

The following table shows the quantities imported* since that time :—

		Dynamite. Lbs.		Gelatinous forms. Lbs.
1882	...	1,008,050	...	—
1883	...	1,920,650	...	—
1884	...	1,085,000	...	—
1885	...	1,068,100	...	—
1886	...	1,073,800	...	20,000
1887	...	707,500	...	No return.
1888	...	1,120,800	...	„
1889	...	1,155,200	...	154,250
1890	...	371,650	...	462,002
1891	...	185,200	...	478,650
1892	...	226,398	...	492,270

DYNAMITE NOS. 1 AND 2, E.C. DYNAMITE, DYNAMITE 1 S., DYNAMITE No. 1 S.B., AND DYNAMITE No. 0.

In 1876, on the passing of the Explosives Act, dynamites Nos. 1 and 2 only were licensed, the following being the authorized composition under Class 3, Division 1 :—

Dynamite No. 1 consisting of not more than 75 parts by weight of thoroughly purified nitroglycerine, uniformly mixed with 25 parts by weight of an infusorial earth, known as "kieselguhr," and sufficiently absorbent in quality when mixed in the above proportions to prevent exudation of nitroglycerine.

* The amount imported is not necessarily for home consumption, a considerable quantity being transhipped to other countries,

Dynamite No. 2 consisting of not more than 18 parts by weight of thoroughly purified nitroglycerine, uniformly mixed with 82 parts by weight of a pulverized preparation composed of nitrate of potash 71 parts, charcoal not less than 10 parts, and purified paraffin (or ozokerit) 1 part (or nitrate of potash 72 parts and charcoal not less than 10 parts) by weight, and sufficiently absorbent in quality when mixed in the above proportions to prevent exudation of nitroglycerine.

The above definition of dynamite No. 2 is extant at the present time (1892).

No change was made in this explosive until 1887, but in 1883, E.C. dynamite and in 1884, dynamite 1 S. were added to the list. Both of these are defined in identical terms, viz. :—

E.C. Dynamite and Dynamite 1 S consisting of not more than 75 parts by weight of thoroughly purified nitroglycerine, uniformly mixed with 25 parts by weight of a preparation consisting of an infusorial earth known as kieselguhr and carbonate of soda, the said preparation being sufficiently absorbent in quality, when employed in the above proportions, to prevent exudation of nitroglycerine. Provided that the amount of carbonate of soda present shall not exceed 3 parts by weight in every 100 parts by weight of the finished dynamite.

In 1886, a company under the name of the Nobel Dynamite Trust Company, Limited, was formed, having for its primary object the acquisition by exchange of shares of certain explosive companies, and this led to a change in the list in the following year.

In 1887, dynamite No. 1 S.B. was licensed temporarily, and as the authorized composition is covered by the new definition of dynamite No. 1 (see below), it is unnecessary to give it here.

A new and more comprehensive definition of dynamite No. 1 was substituted for the former definition. It included the varities known as dynamite No. 1, dynamite 1 S., E.C. dynamite, and the new dynamite No. 1 S.B. Consequently, these four were removed from the (1887) list of explosives, and the authorized compositions became :—

Dynamite No. 1 consisting of not more than 75 parts by weight of thoroughly purified nitroglycerine, uniformly mixed with 25 parts by weight of :—(*a*) an infusorial earth known as kieselguhr, or (*b*) a non-explosive mixture of kieselguhr with such other ingredients and in such proportions as may for the time being be sanctioned by the Secretary of State, provided (1) that the said (*a*) kieselguhr or (*b*) non-explosive mixture shall be sufficiently absorbent in quality when mixed in the above proportions to prevent exudation of nitroglycerine; and (2) that there may be added to the kieselguhr, or non-explosive mixture, an amount of carbonate of ammonium not exceeding 1½ parts by weight in every 100 parts by weight of the finished dynamite.

The Secretary of State has signified his approval of the use of one or more of the following ingredients in admixture with kieselguhr in dynamite No. 1, viz. :—Carbonate of sodium, sulphate of barium, mica, talc, or ochre, 8 parts or (less) by weight in substitution for an equal

amount by weight of kieselguhr. Provided that the total amount of carbonate of sodium present shall in no case exceed 3 parts by weight in every 100 parts by weight of the finished dynamite.

Dr. Dupré in his chemical report for the (1887) year describes the alteration as follows :—The addition of sodium carbonate, barium sulphate, mica, talc, and ochre to the ingredients composing dynamite No. 1 has been authorized subject to the following conditions :—(*a*) That the total amount of these substances shall not exceed 8 per cent. of the finished dynamite. (*b*) That the amount of sodium carbonate shall not exceed 3 per cent. of the finished dynamite.

These additions were asked for mainly in order to reduce the too highly absorbent quality of some kinds of kieselguhr, and thus enable the manufacturer to produce a 75 per cent. dynamite with the absorbing capacities of the infusorial earth nevertheless fully saturated.

In 1890, the addition of sulphate of magnesium to dynamite was approved, but this entailed no alteration in the definition, the object of the addition being to render the dynamite flameless.

No alteration has been made since 1887, and the above are the authorized definitions of dynamite up to the end of 1892.

The makers define the composition of dynamite No. 1 as containing 75 parts of nitroglycerine and 25 parts of kieselguhr.

Dynamite No. 0, a new dynamite, was examined in 1892 and favourably reported on, but does not appear on the authorized list for that year. It consists of 74 parts of nitroglycerine absorbed in 26 parts of nitro-cotton.

Blasting-gelatine and Camphorated Gelatine.

Blasting-gelatine came into existence in 1878, but was not manufactured for general sale previous to 1879. It was licensed under Class 3, Division 1, as follows :—

Blasting-gelatine No. 1, consisting of collodion cotton, as hereinafter defined, combined with thoroughly purified nitroglycerine, and containing not less than 7 and not more than 10 parts of such collodion cotton in every 100 parts, the whole to be of such a character and consistency as to prevent liquefaction or exudation. Collodion cotton, consisting of nitro-cellulose, thoroughly washed and purified, and of such composition that at least 95 per cent. of the dry material shall be soluble in a mixture of ether and alcohol.

In 1880, the above definition was altered, and three new kinds were added to the list. The following being the authorized definitions :—

Blasting-gelatine No. 1, consisting of nitro-cotton, as hereinafter defined, combined with thoroughly purified nitroglycerine, and containing not less than 7 parts of such nitro-cotton in every 100 parts of blasting-gelatine, the whole to be of such

character and consistency as not to be liable to liquefaction or exudation. Nitro-cotton, consisting of nitro-cellulose, carefully washed and purified, and of such composition that not less than 70 per cent. of the dry material shall be soluble in nitroglycerine.

Blasting-gelatine No. 2, consisting of blasting-gelatine No. 1, as above defined, mixed or incorporated with nitrate of potash (with or without charcoal) or such other nitrate as may from time to time be sanctioned by a Secretary of State.

Blasting-gelatine No. 3, consisting of thickened nitroglycerine, as hereinafter defined, mixed or incorporated with one or more of the following non-explosive ingredients, viz.:—Cotton, charcoal, kieselguhr, or such other ingredients as may from time to time be sanctioned by a Secretary of State, the whole to be so mixed and to be of such a character as not to be liable to liquefaction or to separation of ingredients. Thickened nitroglycerine, consisting of thoroughly purified nitroglycerine, combined with not less than 4 parts of nitro-cotton, as above defined, in every 100 parts of thickened nitroglycerine.

Blasting-gelatine No. 4, consisting of blasting-gelatine No. 3, as above defined, mixed or incorporated with nitrate of potash; or such other nitrate as may from time to time be sanctioned by a Secretary of State.

There seem to have been great difficulties in the manufacture of this explosive, and in 1882 its manufacture was suspended. Dr. Dupré in his report gives exudation of nitroglycerine as the cause of every rejection: this led in 1884 to an alteration in the definitions of blasting-gelatine Nos. 1 and 2, and blasting-gelatine Nos. 3 and 4 were removed from the list, reappearing under the designations of gelatine-dynamite Nos. 1 and 2.

In 1884, the authorized definitions were as follows:—

Blasting-gelatine No. 1, consisting of nitro-cotton, as hereinafter defined, combined with thoroughly purified nitroglycerine in such proportions that the whole shall be of such character and consistency as not to be liable to liquefaction or exudation. Nitro-cotton consisting of nitro-cellulose carefully washed and purified.

Blasting-gelatine No. 2, consisting of blasting-gelatine No. 1, as above defined, mixed or incorporated with nitrate of potash (with or without charcoal) or such other nitrate as may for the time being be sanctioned by a Secretary of State.

Blasting-gelatine Nos. 3 and 4 appeared in 1884, under the designation of gelatine-dynamite Nos. 1 and 2.

In 1889, camphor was added to blasting-gelatine No. 1, and the mixture appeared on the list as under:—

Camphorated Gelatine, consisting of blasting-gelatine No. 1, as above defined, mixed or incorporated with camphor.

In 1890, the explosive was again adversely reported upon owing to exudation, which led to a slight alteration in the manufacture, appearing on the authorized list of 1891 under the following definition, viz.:—

Blasting-gelatine No. 1, consisting of nitro-cellulose, carefully washed and purified, combined with thoroughly purified nitroglycerine in such proportions that

the whole shall be of such character and consistency as not to be liable to liquefaction or exudation, and with or without carbonate of calcium or carbonate of magnesium not exceeding 1 part by weight in every 100 parts by weight of the finished explosive.

Blasting-gelatine No. 2. (Same as No. 2 above.)

Camphorated Gelatine, consisting of blasting-gelatine No. 1, as above defined, mixed or incorporated with camphor.

In 1890, the composition of blasting gelatine No. 1 was:—93 to 95 parts of nitroglycerine and 7 to 5 parts of nitro-cotton.

The composition of blasting gelatine No. 1 is stated by the makers in 1893 as:—92 parts of nitroglycerine and 8 parts of nitro-cotton.

There is no change in the definition of the above explosives for the present year (1892), but the samples examined show that the difficulties of exudation and liquefaction have not altogether been overcome.

GELATINE-DYNAMITE.

In 1884, blasting-gelatine Nos. 3 and 4 disappeared from the list and reappeared under the designation of gelatine-dynamite Nos. 1 and 2. In appearance this explosive resembles blasting-gelatine, and occupies a position midway between dynamite and blasting-gelatine. The authorized definitions under Class 3, Division 1, were as follows, viz.:—

Gelatine-dynamite No. 1, consisting of thoroughly purified nitroglycerine, thickened by being combined with nitro-cotton, as hereinafter defined, and mixed or incorporated with one or more of the following non-explosive ingredients, viz.:—Cotton, charcoal, or such other ingredients as may for the time being be sanctioned by a Secretary of State, and in such proportions that the whole shall be of such character and consistency as not to be liable to liquefaction or exudation. Nitro-cotton, consisting of nitro-cellulose carefully washed and purified.

Gelatine-dynamite No. 2, consisting of gelatine-dynamite No. 1, as above defined, mixed or incorporated with nitrate of potash, or such other nitrate as may for the time being be sanctioned by a Secretary of State.

This definition, with slight alteration in the wording, is extant at the present time (substitute nitro-cellulose for nitro-cotton and omit definition of nitro-cotton.)

In 1885, wood-meal, for the bleaching or purifying of which no chemical agents have been used, or if used have been absolutely removed, was authorized as an ingredient in this explosive.

In 1889, the chemical report upon gelatine-dynamite was far from satisfactory owing to exudation, but a more satisfactory report appeared in 1890.

No changes having been made since 1890, the definition of gelatine-dynamite is as above (1884) with a slight alteration of the wording.

The makers define gelatine-dynamite as consisting of:—80 parts of a mixture composed of 93 parts of nitroglycerine and 7 parts of nitro-cotton, and 20 parts of a mixture consisting of 80 parts of nitrate of potassium and 20 parts of wood-meal.

Gelignite.

In 1886, varieties of gelatine-dynamite No. 2, made with 60 to 65 per cent. of thin blasting-gelatine, were issued under the name of gelignite.

The name of gelatine-dynamite No. 2, under which they were originally licensed is, however, still retained upon the boxes, as the official name of the explosive in addition to that of gelignite.

In 1888, the admixture with gelatine-dynamite Nos. 1 and 2 of one or other of the following ingredients to an extent not exceeding 1 per cent. was authorized, viz., carbonate of lime or carbonate of magnesia.

The makers define gelignite as consisting of:—65 parts of a mixture composed of 94 parts of nitroglycerine and 6 parts of nitro-cotton, and 35 parts of a mixture composed of 80 parts of nitrate of potassium and 20 parts of wood-meal.

Gun-cotton.

Gun-cotton is defined at the present time, under Class 3, Division 2, as—

Gun-cotton, consisting of nitro-cellulose thoroughly purified, with or without the addition of carbonate of calcium.

Gun-cotton was first discovered in 1832, under the name of xyloïdine, but no practical result was obtained until 1845. It is largely used for war purposes, the gelatinized forms of nitroglycerine have to a great extent superceded it for mining purposes, its rigidness and bulk precluding its general use in bore-holes.

Saturated gun-cotton is uninflammable and requires an abnormal amount of fulminate to detonate it, but it is easily exploded by the initial detonation of the dry material in contact with it. Gun-cotton does not freeze, neither does any liquid explosive exude from it.

Lithofracteur.

This is somewhat similar to dynamite No. 2, and was one of the six nitroglycerine preparations for which licenses were granted up to December 31st, 1875, and from that time up to the present, no alteration has been made in the authorized definition, which stands as follows under Class 3, Division 1:—

Lithofracteur, consisting of not more than 55 parts by weight of thoroughly purified nitroglycerine, uniformly mixed with 45 parts by weight of a pulverized preparation consisting of 1 part by weight of charcoal, bran, and sawdust (or of any

one or more of the same), 3½ parts by weight of an infusorial earth known as kieselguhr, 2½ parts by weight of nitrate of baryta and bicarbonate of soda (or of either of them), ½ part by weight of sulphur and manganese (or either of them), and sufficiently absorbent in quality when mixed in the above proportions to prevent exudation of nitroglycerine.

Colonel Cundill records in 1889 analyses as below, and remarks that lithofracteur is inferior in explosive power to dynamite No. 1, and is said to be more sensitive to heat. To all intents it is a mixture of ordinary dynamite with a crude sort of gunpowder. It is now rarely used in this country.

	A.	B.
Nitroglycerine	52	70
Kieselguhr and sand	30	23
Powdered coal	12	2
Nitrate of sodium	4	—
Nitrate of barium	—	5
Sulphur	2	—

TONITE OR COTTON-POWDER; LIVERPOOL COTTON-POWDER; OR POTENTITE.

Tonite or cotton-powder was in use at the commencement of the Act (1875), and in 1880 a particular variety of nitrated gun-cotton previously covered by the designation of cotton-powder or tonite was re-named Liverpool cotton-powder or potentite. It was specified under Class 3, Division 2, as :—

Tonite or Cotton-powder No. 1, consisting of gun-cotton thoroughly purified, mixed or impregnated with a nitrate or nitrates.

A variety was licensed in 1881, as follows :—

Tonite or Cotton-powder No. 2, consisting of gun-cotton thoroughly purified, mixed or impregnated with a nitrate or nitrates and charcoal.

Liverpool cotton-powder or potentite was changed in name in 1882, first to potentite cotton-powder and subsequently to potentite. It is defined in identical terms with tonite No. 1.

Tonite or cotton-powder Nos. 1 and 2 were designated in 1887 as tonite Nos. 1 and 2.

A further variety was authorized in 1889, as follows :—

Tonite or Cotton-powder No. 3, consisting of a mixture of thoroughly purified meta-dinitro-benzole, and thoroughly purified gun-cotton mixed or incorporated with one or more of the following ingredients, viz.:—Nitrate of potassium, nitrate of sodium, nitrate of barium, and chalk.

The above definitions stand at the present time.

In 1890, tonite consisted of equal parts of nitrate of barium and gun-cotton. Dr. P. P. Bedson analyzed a sample (1890) as follows :—

Nitrate of barium	48·21
Nitrate of potassium	1·77
Gun-cotton	49·21
Moisture	1·58
	100·77

SAWDUST AND GUN-COTTON-POWDER.

This explosive was licensed in 1876 under Class 3, Division 2, and is authorized at the present time as:—

Sawdust and Gun-cotton Powder, consisting of a mixture of two or more of the following explosives, viz.: Sawdust gunpowder, gun-cotton, and cotton gunpowder.*

PUDROLITHE OR ROCK-POWDER.

Pudrolithe was authorized in 1876, under continuing certificate in Class 2, and amended in 1878, the following being the authorized composition:—

Pudrolithe consisting of a mixture of any two or more of the following ingredients, viz.:—Tan, sawdust, nitrate of soda, nitrate of baryta, charcoal, sulphur, and saltpetre.

This explosive was withdrawn from the list in 1882.

The following composition is given by Colonel Cundill:—Saltpetre, 68 parts; sulphur, 12 parts (or sulphur, 8 parts; powdered gumlac, 4 parts); charcoal, 6 parts; nitrate of barium, 3 parts; nitrate of sodium, 3 parts; sawdust, 5 parts; and spent tan, 3 parts.

SCHULTZE GUNPOWDER AND SCHULTZE BLASTING-POWDER.

Schultze gunpowder was manufactured prior to the Explosives Act, 1875, and in 1876 Schultze blasting-powder was added to the list. The actual date of the invention of the explosive as patented by Mr. Schultze is 1868. The definition of these explosives was altered in 1884, and appeared under Class 3, Division 2, in the list as follows:—

Schultze Gunpowder, consisting of nitro-lignin, carefully purified and mixed or impregnated with a nitrate or nitrates other than nitrate of lead, and with or without starch or collodion (such collodion to consist of carefully purified nitro-lignin dissolved in commercially pure ether and alcohol) or pure solid paraffin, provided that such paraffin shall be free from mineral acid.

Schultze Blasting-powder, consisting of Schultze gunpowder, as above defined, mixed with charcoal or sugar.

In 1892, the definition was altered to the following:—

Schultze Gunpowder, consisting of nitro-lignin, carefully purified and mixed or impregnated with a nitrate or nitrates other than nitrate of lead or nitrate of ammonium, and with or without starch or collodion (such collodion to consist of carefully purified nitro-lignin dissolved in a safe and suitable solvent) or pure solid paraffin, provided that such paraffin shall be free from mineral acid.

Schultze Blasting-powder.—(As above defined.)

In the chemical report for the year 1892, Dr. Dupré reported adversely on the new variety of this powder which differed from the powder already

* Cotton gunpowder is now designated potentite (or tonite or cotton-powder No. 1).

licensed by the presence of one new constituent, which was to serve both as a gelatinizing and as a deadening agent. The new constituent was found to endanger the stability of the powder.

The following is an analysis of the powder under the 1884 definition given by Colonel Cundill:—

Soluble nitro-lignin	24·83
Insoluble nitro-lignin	23·36
Lignin (unconverted)	13·14
Nitrates of potassium and barium	32·35
Paraffin	3·65
Matters soluble in alcohol	0·11
Moisture	2·56

Schultze blasting-powder consists of Schultze gunpowder with the addition of charcoal.

Cooppal Powder.

This explosive was licensed in 1884, under Class 3, Division 2, and is a sporting powder, similar to Schultze powder. The following is the authorized definition which is extant at the present time:—

Cooppal Powder, consisting of nitro-lignin, carefully purified, with or without admixture of a nitrate or nitrates other than nitrate of lead and starch.

Espir Explosive Powder.

This powder was licensed in 1878, and described under Class 2 as consisting of a mechanical mixture of nitrate of sodium, sulphur, and sawdust. It does not seem to have been received with much favour by the public, in 1884 it was no longer manufactured, and disappeared from the authorized list in 1886.

The patent specification (No. 291, 1875) gives the following composition:—Nitrate of sodium, 60 parts; sulphur, 14 parts; and sawdust, 26 parts.

Asphaline.

This is one of the few chlorate mixtures, and was licensed under Class 4, in 1882 as follows, viz.:—

Asphaline No. 1, consisting of a mixture of chlorate of potassium and bran, as hereinafter defined, with or without an admixture of one or more of the following ingredients, viz.:—Nitrate of potassium, sulphate of potassium, paraffin oil, paraffin, ozokerit (such paraffin oil, paraffin, and ozokerit to be free from mineral acid), soap, fuchsine; such mixture to contain not more than 54 parts by weight of chlorate of potassium and 4 parts by weight of nitrate of potassium and sulphate of potassium, or either of them, to every 42 parts by weight of bran. Bran consisting of wheat bran or barley bran, thoroughly cleansed, and reasonably free from flour.

Asphaline No. 2, consisting of asphaline No. 1, as above described, with the addition of nitrate of potassium, in such proportions that the total amount of nitrate of potassium present shall not exceed 25 parts by weight in 100 parts by weight of the finished explosive.

The following was the actual composition :—66 parts of chlorate of potassium and 34 parts of bran.

The manufacture of this explosive was discontinued in 1884, and in 1886, it was removed from the list.

PATENT SAFETY BLASTING-POWDER.

This is a nitrate mixture, licensed in 1881 under Class 2. Its definition has not been altered up to the present time, but the manufacture seems to have been suspended since 1884.

Patent Safety Blasting-powder, consisting of a mechanical mixture of saltpetre, sulphur, lampblack, sawdust, and sulphate of iron.

In the patent specification (No. 3934, 1874), it is defined as follows :—Nitrate of potash, nitrate of soda, nitrate of lime, one, two or three nitrates, in all 50 to 64 parts; sulphur, 13 to 16 parts; tanner's bark (containing refuse animal matter is preferred) or sawdust, or bark and sawdust, 14 to 16 parts; soot or lampblack, or both, 9 to 18 parts; and 5 to 6 parts of sulphate of iron in every 100 parts of the above mixture.

It is recommended to be used as a wash, with about 10 gallons of water to 2 pounds of the compound, as a remedy for *Phylloxera vastatrix*. (Colonel Cundill.)

ROBURITE.

Roburite is a nitro-compound and was authorized in 1887, under the following definition, Class 3, Division 2, viz. :—

Roburite, consisting of a mixture of nitrate of ammonium and thoroughly purified, chlorinated dinitro-benzole, provided that such chlorinated dinitro-benzole shall not contain more than 4 parts by weight of chlorine to every 100 parts by weight of the chlorinated dinitro-benzole.

During 1887, several modifications in the composition of roburite were sanctioned, and in 1888, the following was the authorized definition, which is still extant, viz. :—

Roburite, consisting of (*a*) nitrate of ammonium, with or without an admixture of nitrate of sodium and neutral sulphate of ammonium, or either of them, provided that the amount of nitrate of sodium shall in no case exceed 50 per cent. of the total amount of nitrates present; and (*b*) thoroughly purified chlorinated dinitro-benzole, with or without the addition of thoroughly purified chloro-nitro-naphthalene and chloro-nitro-benzole, provided (1) that such chlorinated dinitro-benzole shall not contain more than 4 parts by weight of chlorine to every 100 parts by weight of chlorinated dinitro-benzole; and (2) that the proportions of chloro-nitro-naphthalene and chloro-nitro-benzole shall not amount to more than 2 per cent. and 5 per cent. respectively of the finished explosive.

Roburite No. 2 appeared first on the authorized list of explosives in 1890, as follows :—

Roburite No. 2, consisting of roburite No. 1, as above defined, with the addition of chloride of ammonium and sulphate of magnesium, or either of them.

This explosive (1890) was said to contain between 5 and 12 per cent. of chlorinated dinitro-benzole containing not more than 4 per cent. of chlorine, mixed with nitrate of ammonium. Samples used appeared to contain 87 parts of nitrate of ammonium and 13 parts of chloro-dinitro-benzole, with traces of carbonate of ammonium and chloro-nitro-naphthalene.

Dr. P. P. Bedson analysed roburite as follows :—

	A.	B.
Makers' mark	Dec. 19, 1889.	Sept. 24, 1890.
Moisture	1·14	0·66
Nitrate of ammonium...	83·35	86·30
Chloro-dinitro-benzene	11·67*	11·74†
Matter insoluble in ether or water ...	3·14	1·09
Fixed residue	0·70	0·21
	100·00	100·00

Carbo-dynamite.

In 1888, a license for a small quantity of carbo-dynamite was taken out, and as no further license was taken the explosive was not kept on the list. In 1889, it re-appeared under the following definition in Class 3, Division 1 :—

Carbo-dynamite, consisting of not more than 90 parts by weight of thoroughly purified nitroglycerine, uniformly mixed with 10 parts by weight of charcoal sufficiently absorbent in quality when mixed in the above proportions to prevent exudation of the nitroglycerine, whether with or without the addition of one or more of the following substances, viz. :—Nitrate of potassium, nitrate of barium, carbonate of sodium, and carbonate of ammonium, provided that the proportion of carbonate present shall not exceed 1½ parts by weight in every 100 parts by weight of the finished explosive.

The above definition is still extant.

The patentee claims that by the addition of 3 to 5 parts of carbonized cork (in lieu of an equal amount of kieselguhr) to ordinary dynamite the latter also becomes capable of resisting the action of water. (Col. Cundill.)

Securit or Securite, Flameless Securite, Compressed Securite.

In 1888, securite was licensed for importation only, and appears as a nitro-compound in Class 3, Division 2, under the following definition:—

Securit, consisting of a mixture of nitrate of ammonium and thoroughly purified meta-dinitro-benzole.

In 1889, it was defined as :—

Securite, consisting of a mixture of nitrate of potassium or nitrate of ammonium with thoroughly purified meta-dinitro-benzole.

* Melted between 78 and 82 degs C. † Melted at 85 degs. C.

In 1889, flameless securite was added to the list.

Flameless Securite, consisting of securite as above defined with the addition of oxalate of ammonium.

This explosive disappeared in the following year (1890), being included in securite as below.

In 1890, securite only appears on the list as follows:—

Securite, consisting of a mixture of nitrate of potassium or nitrate of ammonium, with thoroughly purified meta-dinitro-benzole, with or without the addition of oxalate of ammonium.

In 1890, *stone* securite appeared to consist of 26 parts of dinitro-benzole and 74 parts of nitrate of potassium; and *coal* securite, a mixture of 80 parts of nitrate of ammonium, 17 parts of dinitro-benzole, and 3 parts of oxalate of ammonium.

In 1891, compressed securite appeared as follows:—

ompressed Securite, consisting of a mixture of nitrate of potassium and nitrate of barium (or either of them) with thoroughly purified nitro-cellulose and one or more of the following substances:—Thoroughly purified meta-dinitro-benzole, thoroughly purified dinitro-toluol, thoroughly purified nitro-naphthalene, thoroughly purified dinitro-naphthalene.

The above two definitions are extant at the present time.

Denaby Powder.

This explosive first appeared on the authorized list of 1891-2:—

Denaby Powder, consisting of compressed securite, as above defined, with the addition of charcoal.

Bellite.

This explosive was licensed for importation only in 1888, and it was entered under Class 3, Division 2, as follows:—

Bellite, consisting of a mixture of nitrate of ammonium and thoroughly purified meta-dinitro-benzole.

This definition is extant at the present time.

Bellite appears to be a mixture of about 80 parts of nitrate of ammonium and 20 parts of meta-dinitro-benzole.

Di-flamyr.

This explosive was licensed in 1888, and appears under Class 3, Division 2, up to the present time. It is defined as—

Di-flamyr, consisting of nitro-cellulose, thoroughly purified, mixed or impregnated with a nitrate or nitrates other than nitrate of lead.

Carbonite.

Carbonite was licensed in 1888, under Class 3, Division 1, the definition remaining unaltered up to 1892, when a slight alteration was made.

In 1888, it was composed as follows:—Nitroglycerine, 25 parts (with or without ½ part of sulphuretted-benzole); wood-meal, 40 parts; nitrate

of potassium and nitrate of sodium, either or both, 34 parts; and carbonate of sodium, ½ part.

In 1892, nitrate of barium and carbonate of lime were added as ingredients. The definition then appeared as follows:—

Carbonite, consisting of not more than 25 parts by weight of thoroughly purified nitroglycerine (with or without the addition of not more than ½ part of sulphuretted benzole) uniformly mixed with 75 parts by weight of a pulverized preparation consisting of wood-meal not less than 40 parts; nitrate of potassium, nitrate of sodium, and nitrate of barium (one or more of them) 34 parts; and carbonate of sodium and carbonate of lime (or either of them) not more than ½ part, such preparation to be sufficiently absorbent when mixed in the above proportions to prevent exudation of nitroglycerine.

The makers state the composition of carbonite to be as follows:—Nitroglycerine, 25 parts; nitrate of potassium, 30 parts; nitrate of barium, 4 parts; wood-meal, 40 parts; and carbonate of sodium, 1 part.

Favier Explosive, Miner's Safety Explosive, or Ammonite.

Favier explosive was licensed in 1888 under the designation of miner's safety explosive, and its name changed to ammonite in 1889.

In 1890, the composition was:—10 parts of mononitro-naphthalene and 90 parts of nitrate of ammonium.

In 1892, dinitro-naphthalene was added, and the definition at present stands under Class 3, Division 2, as follows:—

Ammonite, consisting of a mixture of nitrate of ammonium, and thoroughly purified mononitro-naphthalene or dinitro-naphthalene, or a mixture of the two last-named ingredients, made up into cartridges for blasting not containing their own means of ignition, contained or enclosed in a thoroughly waterproof case.

In 1893, a sample was analysed as follows:—

	Per Cent.
Dinitro-naphthalene	12·54
Nitrate of ammonium	87·46
	100·00

Fortis Explosive.

Fortis explosive was licensed in 1888 under Class 2, and defined as follows, viz.:—

Fortis Explosive, consisting of a mixture of two or more of the following substances, viz.:—Tan, lampblack, and sulphur, such mixture being thoroughly impregnated with a mixture of nitrate of potassium and proto-sulphate of iron, and with or without the addition to such impregnated mixture of glycerine,

This explosive is authorized for importation and issued only in the form of compressed cartridges, such cartridges being rendered thoroughly waterproof (*a*) by waterproofing the naked compressed cartridges and (*b*) by enclosing such waterproof compressed cartridges in a thoroughly waterproof cartridge-case. The above definition is extant at the present time.

The component parts are :—Sulphur 12, charcoal 11, ferrous sulphate 5, nitrate of potassium 62·5, moisture 2·5, and organic sulphide 7.

Fortisine.

This explosive is also called Fortis No. 2, and was licensed in 1892, under Class 3, Division 2, as follows, viz.:—

Fortisine, consisting of a mixture of saltpetre, sulphur, and charcoal with the addition of a dinitro-benzole and resin or dextrine, provided, 1st, that the amount of dinitro-benzole shall not exceed 5 per cent. of the finished explosive; and 2nd, that all the ingredients shall be thoroughly purified.

Ballistite.

Ballistite is a blasting-gelatine, licensed in 1889; and a slight alteration was made in the definition in 1890. It appears in 1892 under Class 3, Division 1, and is defined as follows :—

Ballistite, consisting of nitro-cellulose, carefully washed and purified, combined with thoroughly purified nitroglycerine, with or without the addition of camphor, aniline, and such other substance, and solvent (if any) as may from time to time be approved by a Secretary of State, and with or without carbonate of calcium or carbonate of magnesium not exceeding 1 part by weight in every 100 parts by weight of the finished explosive, the whole to be of such character and consistency as not to be liable to liquefaction or exudation.

It is composed of from 2 to 1 parts of nitroglycerine, with from 1 to 2 parts of nitro-cellulose.

Stonite.

Stonite was licensed in 1889. The definition, under Class 3, Division 1, has remained unaltered since then, as follows :—

Stonite, consisting of not more than 68 parts by weight of thoroughly purified nitroglycerine, uniformly mixed with 32 parts by weight of a preparation consisting of nitrate of barium, nitrate of potassium (or either of them), kieselguhr (not less than 20 parts by weight), wood-meal (not less than 4 parts by weight), and carbonate of magnesia, with or without the addition of sulphuretted oil and soot (or either of them), such preparation to be sufficiently absorbent when mixed in the above proportions to prevent exudation of nitroglycerine.

It is composed of 68 parts of nitroglycerine, and charcoal, kieselguhr, and wood-meal 32 parts.

Picric Acid.

Picric acid was licensed as an explosive in 1889 (with no alteration up to the present time), and defined under Class 3, Division 2, as follows :—

Picric Acid, consisting of trinitro-phenol containing not more than 0·5 per cent. of mineral matter or ash.

Picric acid or trinitro-phenol ($C_6H_3(NO_2)_3O$) is obtained by the action of nitric acid on carbolic acid. It is a yellow crystal used largely as a dye. When heated in contact with certain metallic salts or oxides, it explodes violently. It is seldom if ever used as a blasting agent owing to the

large percentage of carbonic oxide given off. Owing to a disastrous explosion at Messrs. Roberts, Dale & Co.'s chemical works, near Manchester, in 1887, picric acid was brought within the scope of the Explosives Act, with certain exceptions.

Gathurst Powder.

Gathurst powder appeared on the 1890 list, without comment, as a new explosive, under Class 3, Division 2, and is extant at the present time.

Gathurst Powder, consisting of a mixture of (*a*) nitrate of potassium or nitrate of sodium, with or without the admixture of neutral sulphate of ammonium, nitrate of ammonium, chloride of ammonium, sulphate of magnesium, and a colouring matter, such as charcoal or lampblack (free from mineral acid), or all or any of them; and (*b*) thoroughly purified nitro and chloro-nitro compounds of benzine, toluene, and naphthalene, with or without such other substances as may from time to time be approved by a Secretary of State. Provided that the finished explosive shall not contain more than 2 parts by weight of chlorine in every 100 parts of the finished explosive.

The composition is chloro-dinitro-benzole 1 part, nitrate of potassium 4 parts, nitrate of ammonium 2 parts, and colouring matter *ad lib.*

Smokeless Powder and Smokeless Blasting-powder.

Smokeless powder was licensed in 1888, and smokeless blasting-powder in 1891, under Class 3, Division 2, and they are defined at the present time (1892) as follows:—

Smokeless Powder, consisting of nitro-lignin, carefully purified and mixed or impregnated with a nitrate or nitrates (other than nitrate of lead and ammonium nitrate), and with or without starch or collodion, or turmeric or similar vegetable colouring matter, provided that such collodion shall consist of carefully purified nitro-lignin dissolved in a safe and suitable solvent, and with or without such other substance as may from time to time be approved by a Secretary of State.

Smokeless Blasting-powder, consisting of smokeless powder, as above defined, with the addition of any one or more of the following ingredients, viz.:—Dinitro-benzole, dinitro-toluol, nitro-benzole, and nitro-naphthalene, provided that all such ingredients shall be thoroughly purified.

Its composition is nitro-cotton 65 parts, nitro-toluol 9 parts, nitrate of barium 20 parts, nitrate of potassium 4 parts, and chalk 2 parts.

Forcite.

This explosive was licensed in 1891, under Class 3, Division 1, and was defined as under:—

Forcite, consisting of thoroughly purified nitroglycerine, thickened by being combined with nitro-cellulose, carefully washed and purified, and mixed or incorporated with wood-meal and nitrate of potassium, in such proportions that the whole shall be of such character and consistency as not to be liable to liquefaction or exudation.

The above definition is extant at the present time.

Oarite.

Oarite was licensed in 1891, under Class 3, Division 1, and was defined as follows :—

Oarite, consisting of not more than 2 parts by weight of thoroughly purified nitroglycerine, uniformly mixed with 8 parts by weight of the following preparation, viz. :—Thoroughly purified nitro-cellulose 1 part, thoroughly purified dinitrobenzole 1 part, nitrate of barium or nitrate of potassium, or either of them, 6 parts, provided that the said preparation shall be sufficiently absorbent in quality when mixed in the above proportions to prevent exudation of nitroglycerine.

The above definition is extant at the present time.

Ardeer Powder.

Ardeer powder was licensed in 1891 under Class 3, Division 1, and was defined as follows, viz. :—

Ardeer Powder, consisting of dynamite No. 1, as above defined,* mixed or incorporated with sulphate of magnesium.

In 1892, an alkaline nitrate was added to the powder, and it appears on the list at the present time as follows, viz. :—

Ardeer Powder, consisting of dynamite No. 1, as herein defined,* mixed or incorporated with sulphate of magnesium, with or without the addition of nitrate of potassium, nitrate of sodium, nitrate of barium, or such other nitrates as may from time to time be approved by the Secretary of State.

The composition of ardeer powder is defined by the makers as follows : —Nitroglycerine 33¾ parts, charred kieselguhr 11¼ parts, and sulphate of magnesium and nitrate of potassium 55 parts.

Blasting Matagnite and Matagnite-Gelatine.

These explosives appeared on the 1891 list, under Class 3, Division 1, and are defined at the present time as follows :—

Blasting Matagnite, consisting of nitro-cellulose, carefully washed and purified, combined with thoroughly purified nitroglycerine and thoroughly purified nitro-benzole, or either of them, in such proportions that the whole shall be of such character and consistency as not to be liable to liquefaction or exudation.

Matagnite Gelatine, consisting of thoroughly purified nitroglycerine and thoroughly purified nitro-benzole, or either of them, thickened by being combined with nitro-cellulose, carefully washed and purified, and mixed or incorporated with wood-meal, for the bleaching or purifying of which no chemical agents have been used, or, if used, have been absolutely removed, and nitrate of potassium or such other nitrate as may for the time being be sanctioned by a Secretary of State, in such proportions that the whole shall be of such character and consistency as not to be liable to liquefaction or exudation.

It is said to consist of nitroglycerine 65 parts, nitro-cellulose 4 parts, nitrate of potassium 24 parts, and wood-meal 7 parts.

* See page 349.

GREENER POWDER.

This explosive was licensed in 1891, under Class 3, Division 2, as follows:—

Greener Powder, consisting of a mixture of thoroughly purified nitro-cellulose with thoroughly purified nitro-benzole, or either of them, with the addition of colouring matter consisting of graphite, lampblack, or other suitable material, such colouring matter to be free from free mineral acid.

CANNONITE NOS. 1 AND 2.

These explosives were licensed in 1892, under Class 3, Division 2, and were defined as follows:—

Cannonite No. 1, consisting of gun-cotton (consisting of thoroughly purified nitro-cellulose) mixed or impregnated with a nitrate or nitrates (other than nitrate of lead or nitrate of ammonium) and resin, and with or without the addition of graphite.

Cannonite No. 2, consisting of gun-cotton (consisting of thoroughly purified nitro-cellulose) mixed or impregnated with resin, and with or without the addition of graphite.

TROISDORF SMOKELESS POWDER.

This explosive was licensed in 1892, under Class 3, Division 2, and was defined as follows:—

Troisdorf Smokeless Powder, consisting of thoroughly purified nitro-cellulose gelatinized by a suitable process, and with or without the addition of nitrates (other than nitrate of ammonium).

AMBERITE NOS. 1 AND 2.

Amberite No. 1 was licensed in 1892, under Class 3, Division 1, as follows:—

Amberite No. 1, consisting of thoroughly purified nitro-cellulose mixed or combined with the following substances:—Thoroughly purified nitroglycerine, paraffin free from mineral acid, and shellac. The whole to be of such character and consistency as not to be liable to liquefaction or exudation.

Amberite No. 2 was licensed in 1892, under Class 3, Division 2, as follows:—

Amberite No. 2, consisting of thoroughly purified nitro-cellulose, whether or not mixed or impregnated with nitrate of potassium and nitrate of barium, or either of them, and with or without the addition of paraffin, vaseline, and graphite, or such other substance as may from time to time be approved by a Secretary of State.

The meeting then closed.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE QUEEN'S HOTEL, LEEDS, OCTOBER 21ST, 1893.

MR. W. E. GARFORTH, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected Members of the Institute, having been previously nominated :—

Mr. ARTHUR BRITTON, Colliery Surveyor, Wigan.
Mr. JOHN GILL, Manager, Lofthouse Colliery, Wakefield.
Mr. J. HERBERT HOLLINGS, Colliery Manager, Wath Main Colliery, near Rotherham.
Mr. ISAAC JONES, Mining Engineer, Wynnstay Collieries, Ruabon.
Mr. ALF. PEARSON, Civil and Mining Engineer, Dukinfield, near Manchester.
Mr. JOHN FREDERICK ROBINSON, Mechanical Engineer, Elland.
Mr. WM. GILBERT ROBINSON, Mechanical Engineer, Elland.
Mr. ROBERT ROWAND, Mining Engineer, Wakefield.

Mr. A. W. BENNETT read the following paper on "The Best Means of Conveying Electric Energy in a Fiery Mine" :—

THE BEST MEANS OF CONVEYING ELECTRIC ENERGY IN A FIERY MINE.

BY A. W. BENNETT.

The use of electrically worked plant and apparatus having now become so general at collieries and elsewhere, it appeared to the writer that the subject of the conveyance and distribution of electric energy might be one worth considering in itself, without going, for the time being, into details of the plant, apparatus, etc., used to convert energy to and from its electric form; the more especially as he has seen suggestions and even practical applications of such means of conveying the electric current which might endanger a mine where explosive gas is present.

As will be surmised, this remark applies but little to the applications of electric energy for signalling and telephony.

Here the chances of danger from any source, either shocks or explosions, are infinitesimal if they exist at all: whilst the apparatus forms a very useful and inexpensive adjunct to the safe working of a colliery. Just a word may be said in passing as to the running of the wires, which are usually of bare galvanized iron, placed on suitable insulators to keep them close to the top or side walls of a road to be out of the way, yet kept clear. To work the bells, etc., with economy and certainty, where part of a battery circuit should have a high electric resistance, care should be taken both in the matter of connecting up and insulating of the wires, and keeping them as free from dirt and water as possible by reasonably frequent cleaning, to prevent waste of battery power and failure of bells to ring.

Coming to the applications of electric energy for lighting and transmission of power, let us take first the safety question, for however economical a system may be, a mining engineer might well pause before recommending it, if there was even a remote chance of its bringing a new and serious source of danger into a mine. The writer's opinion is that to take small wires unprotected into a fiery mine and send a considerable electric current through them, they being in a place where they may get broken by falls or accidents or mischief, is tantamount to taking ordinary lucifer matches into the pit. But if we could enclose the matches (as we do our light in the ordinary safety-lamp), so that either they cannot get ignited, or if

they do ignite, cannot communicate flame or heat sufficient to ignite the outside air, the objections on that score would be overcome. The writer maintains that this can be done with electric wires rendering them perfectly safe, or at least scarcely more dangerous than a good safety-lamp if as much so.

As to the means of doing this the following precautions may be suggested:—

1. The employment of competent men to run the wires and do all the responsible work, and every part of the apparatus should be tested for continuity and insulation from time to time after completion of fixing.

2. The wires and cables (stranded wires) should have a covering of some good and lasting insulating material to prevent contact between wires, leakage to earth of the electric current, and corrosion of wires. The substance which has proved itself far ahead of all others for flexibility and resistance to deterioration is indiarubber, as applied by the principal wire-coverers of to-day; namely, two coats of rubber, one pure and one vulcanized, are wrapped on the wire, then rubber-coated tape, and the whole being vulcanized into one mass without cracks or fissures by heating. The wires are then tested after 24 hours' immersion in salt water, guaranteed to give a certain minimum insulation per mile, and covered with braiding, tape, etc., to suit requirements. Those with a guaranteed insulation-resistance of 300 to 700 megohms are usually good enough for colliery purposes, but not too good if safety and durability are to be considered.

3. Wood-casing, although usual for buildings and dry places on the surface, is generally unsuitable for underground work. It can only be tolerated there if very strong and thick, and if hard wood that will not easily crack or absorb moisture is used. Round a downcast pit bottom, in two instances, the writer, for safety, took wires out of casing and led them on insulators on the rock-arching. A better (in fact, the writer thinks by far the best) protection is to run the wires in an iron pipe, the two wires or cables in one pipe of sufficient internal diameter to allow them to be separately drawn through and to lie loosely in the pipe. Joints in the wires should be well soldered with resin not spirits, and well covered with rubber and rubber-proof tape, filled in with rubber solution, and the joints and the ends of the pipes should be made waterproof with white lead or equivalent substance. For connecting-places, suspension in shaft, etc., waterproof junction-boxes of malleable cast-iron and the lid bushed with indiarubber can be inserted in the iron piping at as many places as desired. The pipes should be strong enough to withstand

a considerable fall of roof or being run over by a few corves, in which case they could, for ease and cheapness of construction, be laid on one side of the floor of the road and carried either under or over where required.

As a protection for wires from water, etc., lead covering is often resorted to. The writer knows of instances where this has worked well, the cables being led in strong wood casing down shafts, etc.; and he also knows of cases where it has failed, with serious results, so far as expensive renewals being rendered necessary. In most cases, however, where they have failed, it has been owing to a lower priced substance, such as bitumen or fibre saturated with bitumen being used instead of indiarubber. Once a path is formed for a very small quantity of current, a local electrolytic action quickly converts the lead into oxides, and at the surface exposed to the air into carbonates, which fall away as a moist powder, so that generally the use of lead coverings can not be recommended.

Wires and cables are sometimes laid in troughing filled in with bitumen, but this, like the lead covering and the concentric cables, does not permit of drawing out for testing or renewal or repairs, as a system of pipes and junction-boxes does, so that the latter system seems to the writer the best. Exception may be made in places, such as pit bottoms, where naked lights are permitted and where falls of roof are not likely to occur. Here the wires, covered as specified above, can be run on insulators, any portions liable to become wet being shielded to keep water off.

A special cable (the Atkinson*) has been brought forward in which there is an auxiliary conductor coiled round the main one which, in the event of the cable being cut or crushed, acts through an electro-magnet to cut off the current entirely and prevent a dangerous arc being formed in either itself or the main; but, on the ground of prevention being better than cure, the writer thinks money can be better spent in thoroughly protecting ordinary cables, so that they cannot get broken or their insulation destroyed. For shifting machinery, such as coal-cutters, a very flexible conductor well covered, in addition to the rubber, with jute to a considerable thickness, and coiled so as not to be strained, with just sufficient length on the coil and led from one of the junction-boxes, will probably meet requirements. A flexible steel-sheathed cable might be used in some cases. Motors should be entirely encased, also lamps as far as possible, in strong lanterns with globes, and the attachment of lamps to holders should be made with lugs and screws in preference to the ordinary

* *Trans. Fed. Inst.*, vol. iii., page 284.

bayonet socket-holders where, in the event of a spring being or becoming weak, heating and sparking occasionally occur.

Though heating may occur from having the wires too small for the current they have to pass, it is not very frequent that it is caused by this restriction of size, as the loss of energy thereby occasioned greatly exceeds any benefit that economy in the size of wire may give. In most cases four or five times the maximum normal current at least could be passed through the wires without danger of overheating.

Some fire office rules demand the copper section to be 1 inch for 1,000 ampères, but if wires be not coiled up, current at the rate of 4,000 to 5,000 ampères per square inch can generally be sent through wires and cables up to, say, 7/16, and with very small wires even more; but with large wires and cables considerably less will cause heating, so that the larger the cable the greater allowance for safety must be made.

For these and reasons of cost, cables should be kept as small as possible consistent with safe and economical working. This appertains in a greater degree in town supplies where two distinct systems, the continuous current low tension and the alternating high tension, are employed; either may be best according to circumstances. With the continuous, the supply is direct from dynamos to lamps, motors, etc., and the voltage for a two-wire system, 110 volts, or 220 volts for a three-wire system.

Collieries are almost invariably lighted with from 65 to 110 volts. For tramways, electric railways, and for motive power-transmission at collieries, 300 to 500 volts is most usual.

With an alternating-current system, the electric current is generally sent through the cables at an electromotive force of 2,000 volts, and transformed at the places it is wanted to 100 or 50 volts. The wires are almost invariably led in iron pipes with iron junction-boxes, and the transformers are likewise iron-cased. The low-tension wires only are accessible to others than those whose business it is to look after the maintenance of the wires. This system has only in a few cases been applied to collieries, but in certain cases, particularly the transmission of large powers for a considerable distance, it promises to make convenient, easy, and reasonable in cost what hitherto has been cumbrous and expensive.

To make the matter clear to all, it may be explained that the amount of energy transmitted varies as the current or ampèrage multiplied by the electromotive force or voltage, whilst the carrying power and the loss of voltage (in volts, not in proportion of total voltage) in the cables is proportional to the current or ampèrage only, and is independent of the voltage. Hence to economize in the size of cables, high tension must be used in cases where much energy has to go far.

To take an example or two, 10 horse-power could be transmitted at a loss of 20 per cent., a distance of 1,000 yards, as follows :—

At 100 volts by two 37/14 cables, costing nearly £600.

At 500 volts by two 7/19 cables, costing £52.

At 2,000 volts by two No. 21 wires, costing £12.

This is allowing 300 megohms insulation for 100 volts, 750 for 500 volts, and 2,000 for 2,000 volts. In this case, the cost of the transformer and extra for generating dynamo and motor would render 500 volts direct current, the most economical in first cost and probably also in the maintenance. But taking 100 horse-power under the same circumstances the same distance with the same proportion of loss of power or energy in the cables; and omitting 100 volts as impracticable, we have ;—

At 500 volts two 19/14 cables, costing £350.

At 2,000 volts two 7/20 cables, costing £45.

Allowing £150 for transformers and extra for alternating dynamo and motor, this would show £150 in favour of the 2,000 volts alternating system besides the convenience and saving in having smaller cables and pipes ; a 1 inch gas pipe or steam pipe would comfortably carry the two 7/20 cables. In the above figures the loss in transformers has been included in the 20 per cent. and taken at 5 per cent.

In conclusion, a brief reference to accumulators or secondary batteries may be made. For very light work in out-of-the-way places, or for a power which can be taken from place to place, a set of accumulators with a motor on corves or bogies might be very handy, and it is interesting to learn that some now made (the Epstein) are being guaranteed to stand very rough use and even frequent complete overturning. At present, however, their most promising feature for mining engineers is for the portable lamp, which is almost outside our present subject, and one which time will not permit us to refer.

There are several matters which the writer fears he has not fully explained, but the paper is perhaps already too long and he will be glad to explain if desired to do so.

Mr. J. Nevin said he had tried lead-covered cable down a shaft, but found it did not answer. The insulation between the wire and the lead was not sufficiently good, and the current seemed to get across from the wire into the lead : in places the lead was actually melted. He had taken it out and placed indiarubber cable down the shaft.

The President said that his experience was the same.

Mr. THIRKELL said he had done the same.

Mr. BENNETT said he had come to the same conclusion.

Mr. J. LONGBOTHAM moved a vote of thanks to Mr. Bennett for his paper.

Mr. NASH, in seconding the proposition, asked Mr. Bennett if he could give information as to the principle on which the transformer worked in reducing a high-tension current to a low-tension current? He could not see how it acted to bring it from 2,000 to 150 volts.

The motion was put and carried unaminously.

Mr. BENNETT said he was much obliged for the vote of thanks. He was extremely gratified to find that what he had said about lead cables had been verified by members of the Institute. The transformer in principle was very simple—many of the members must have played with induction coils, they must have seen the battery without the coil incapable of giving shocks, and have seen high tension produced from the induction coil capable of giving shocks. The transformation took place in this way: a magnet was energized by a current of electricity being sent through wire wound round it. In a simple induction-coil the electricity was sent through a small coil of one or two layers of wire; a large current of electricity went through that wire at low tension. That current had but little tension, but every turn of it increased the magnetic power of the iron round which it was wound. Outside that coil were wound, say, thirty or forty layers of very fine wire. When the magnet was acted upon by the making and breaking of this primary current, it acted inductively and formed another current in the fine wire, and there being so large a number of turns in the wire round the magnet a current of very much higher tension was produced in that wire than in the primary. They had in a simple induction-coil a transformation of low tension into high tension. The transformer was the same thing reversed—in that case the primary current was sent a great many times through thin wire round the magnet, and the secondary only a few times with the thick wire, and so they had the transformation from a high to a low-tension current. The thickness of the wire allowed a much more powerful current to be generated than in the high-tension circuit.

The discussion was then adjourned.

Mr. C. DUNBAR contributed the following paper on "Coal-dust in Mines and its Relation to Explosions":—

COAL-DUST IN MINES AND ITS RELATION TO EXPLOSIONS.

By C. DUNBAR.

The author believes the subject he has chosen for this paper is an important one, and one which is occupying the attention of many inspectors of mines, colliery managers, and practical miners. Though many opinions have been expressed in favour of the theory of coal-dust explosions, and numerous experiments made to prove it, many persons still doubt the theory and continue to experiment.

The author does not for a moment doubt the right of these persons to their opinions, but he considers that the evidence produced by the inspectors of mines and other eminent gentlemen, who, having made this a special study, declare, after many careful experiments, that coal-dust has been the cause of several of the most disastrous explosions in modern times, must be taken to have great weight.

In the opinion of many of the objectors to the coal-dust theory, coal-dust in hot mines, being very inflammable, only greatly intensifies the force of the explosion for long distances in the main roads. The Messrs. Atkinson, after careful investigation at some of the most extensive explosions of late years, found that at Seaham colliery, which is a dry and hot pit, the explosions had traversed some of the main roads for a distance of 7,500 yards, killing 164 men and boys and 181 horses and ponies. After investigations at Tudhoe in 1882, Usworth in 1885, and Elemore in 1886, experience taught them that the whole of these explosions were caused by the explosion or ignition of coal-dust by shot-firing on the main or intake air-roads, where there was no fire-damp whatever.* The impossibility of air being charged with gas when it comes direct from the downcast shaft without passing over any of the workings whatever, and the distinctive features in all the above explosions of the force and flame traversing the main intake airway and haulage-roads, and not the return airways, leaving the damp or wet roads untouched (clearly indicating that there was nothing in the damp roads to feed the flame on its forward motion), convince the author that coal-dust has been the sole cause of many disastrous explosions.

* *Explosives in Coal-mines*, by Messrs. W. N. and J. B. Atkinson, London, 1886.

Heavy or blown-out shots, large falls of roof causing shocks in these warm and dusty mines, easily raise the dust, which is naturally of a high temperature and in very fine particles, into a cloud, the ignition taking place at the flame from the shot. The flames thus started in their progress considerably raise the temperature of the dust in front and render it more inflammable, increasing the danger owing to the gases evolved.

The question of how the dust is formed is not difficult to answer, and the author trusts that the repetition will be pardoned; in addition to the small dust formed in the actual working of the coal, there is the dust formed in the cleavages of the seam from the dant or rotten coal found in them; these two classes at the face, owing to the slowness of the air-current, are generally deposited on the floor; and in the deep mines, where the air is very dry and moisture is absent, a fair accumulation takes place. The accumulations of coal-dust at the face are not so much dreaded. It is, however, in the main haulage-roads, where a large quantity of coal is hauled or carried and the air moving at very high velocities, that coal-dust accumulates most and exists in the most dangerous state. For main haulage-roads are generally the main intake airways, and the air passing at a high velocity inward sweeps over the rapidly passing train of corves loaded with coal, raising as a cloud the dust which is produced by the shaking and grinding of the coal inside the corves.

As an example, take a main-and-tail-rope engine-plane, where the speed of the tubs is say 6 miles per hour, roughly speaking 500 feet per minute (much higher speeds are common); suppose the area of the roadway is 48 feet, the tubs filling about 10 square feet of this area, and if the quantity of air passing is equal to 25,000 cubic feet per minute, its velocity in an area of (48 — 10 =) 38 square feet will be about 684 feet per minute. Therefore the tubs will be swept by a current of air at a velocity of (684 + 500 =) 1,184 feet per minute. The heavier particles of dust fall to the floor, and the fine light particles, which are small enough to pass through the meshes of a standard wire gauze, adhere and settle upon the roof and sides and timber.

In course of time the train roads become covered with dust along their entire length; the dust which is on the floor has to be frequently removed, as it fills up the roadways, while the dust on the roof and sides, which is like soot, is left to accumulate. It is this fine sooty part which is most inflammable, and probably becomes more so the longer it remains. On examination this dust is found to have a brown appearance.

It has been stated that 1 lb. of this dust in 160 cubic feet of air

forms an inflammable mixture, so that a drift with an area of 48 feet would require the disposition of 1 lb. of dust on the surface of each 3½ feet of the length of the road; the author feels sure that more than this quantity is present on the roof and sides of main roads, without including the dust on the floor.

The high velocity of the air-currents might be thought sufficient to prevent the accumulation of coal-dust, but it is not so: it favours rather than prevents the accumulation, as shown above.

In ordinary conditions of temperature or pressure it has been said that coal-dust and air cannot explode, but that fire-damp must be present to cause an explosion (this the author is afraid is the opinion of a large number of practical miners at the present time), and this is the theory advanced by Mr. W. Galloway, who says that 1 per cent. of fire-damp in coal-dust and air is sufficient to make an explosive mixture. Sir Frederick Abel says it requires from 2 to 2½ per cent. to make it explosive. These opinions, the author considers, are not in keeping with the knowledge and everyday experience gained in mines, as even the larger quantity, 2½ per cent., forms such a very small cap on the flame of the safety-lamp, that in practice it is not easily detected, so that a man examining a place with a safety-lamp would find it next to an impossibility to detect so small a quantity as 2½ per cent. of fire-damp, and, further, 2½ per cent. of fire-damp and air is not an explosive mixture.

How, then, do explosions occur if coal-dust is not the prime mover? The author agrees with the above gentlemen that where there is an explosion of fire-damp and air the coal-dust intensifies it.

In the author's opinion, where coal-dust and air are present in proper proportions with the heat and flame from a shot, there will be an explosion, and if fire-damp be present, even in small proportions, such as 1 per cent. or 2½ per cent., an explosion will be intensified. It will thus be seen that where much fine coal-dust is present the safety or danger of firing a shot cannot be decided by simply examining with a safety-lamp as to the presence of fire-damp, but other considerations must be taken into account before the safety of firing shots in a certain place can be decided on. Whenever an explosion has taken place in any of the various ways mentioned it has been observed that the flame is always greatest when the shot has been stemmed with coal-dust or coal, more especially if the hole has been overcharged.

The damage done is often very great, especially in the intake airways, where, as stated before, the largest and driest quantity of coal-dust is present as well as the driest air, yet the damage done by the blast is usually

found not to extend far (probably not more than 70 or 80 yards) beyond the limit to which the flame has reached. This may be explained by the fact of air and all gases being perfectly elastic.

From observations and a few experiments which the author has made he cannot help reiterating his conviction that coal-dust has been the cause of many an explosion where shots have been fired in dusty roads.

After these preliminary remarks the author considers sufficient has been said on this part of the subject, and he will endeavour to show what he thinks are the best means to adopt in order to avoid such calamitous explosions and the danger of coal-dust.

A common practice now is to water the main roads, and for this purpose water-tubs of various kinds are used. One has a perforated pipe attached to it, and is drawn along behind the sets of tubs, but as this method only waters the floor and leaves the roof and sides practically untouched with the water the dust remains as dangerous as before. Another water-tub has been used, which waters both roof and sides by means of a pump fixed inside, and worked by cranks on the axles of the wheels throwing out the water and air in thin sprays from jets or roses.

Another kind of tub has a brush at one end, and the motion of the wheels makes the brush whirl round, causing the water to fly out from its circumference, and watering all parts of the road alike.

There is still another method, viz., of laying 1½ or 2 inches pipes from the pump column in the shaft along the main road, having a rose or jet fixed on upright standards attached to these pipes, and emitting a constant discharge of thin fine spray of water into the air; this is very successful in laying the dust for a time.

In all these methods, however, there is the strong objection that the water in most cases loosens the top and side stone, rots the timber, and causes the bottom to lift, thus entailing great trouble and expense, as in the main roads the water must be liberally used, or the dry air-current will soon dry it up.

Salt has also been used, to what advantage the author cannot say, but its use will no doubt be very expensive.

After considering all the advantages and disadvantages of the above methods the only practical and safe method in dealing with this danger in mines is to have the dust removed by brushing the roof and sides of the main intake airways at short periods, say every six months; no doubt some expense would be incurred in doing this, but in the author's opinion this would be the best method to use, as the fear of the bottom lifting or the

sides crumbling and wasting as they do when water has to be so often used would be removed. This trouble would be amply repaid by the satisfaction of mind that all had been done to render the roads safe so far as the coal-dust was concerned.

The author knows he has laid a very important subject before the members, and trusts that it will meet with a full discussion, as this cause and effect of explosions being doubtless known to all, it is most important that the opinions of all should be expressed with the intention, if possible, of suggesting some method of dealing with coal-dust in mines.

The PRESIDENT said in his own experience he found that it was impossible to get rid of the very fine particles of dust. Using a brush as suggested would cause some of the coarser particles to be reduced to fine particles, which would become lodged in the interstices of the roof and other places. He did not think they could possibly get rid of those fine particles. After an explosion some of the dust showed that it was not burnt. Of two particles joining each other, one was found to be entirely charred like a piece of coke and the other was untouched. Then there was the question of dirt-dust, and there was a great difference between dirt-dust and coal-dust. It was found at Altofts colliery that the effects of the explosion ceased at points where the dirt-dust roads commenced.

Mr. NEVIN moved a vote of thanks to Mr. Dunbar for his paper.

Mr. CHILDE seconded the motion, which was agreed to.

DISCUSSION ON MR. A. H. STOKES' PAPER ON "A SAFETY-LAMP WITH STANDARD ALCOHOL-FLAME," ETC.*

Mr. BONSER exhibited and described a Gray safety-lamp adapted for detecting small percentages of gas down to ½ per cent., by Mr. A. H. Stokes, H.M. Inspector of Mines, by means of an alcohol-flame, and said he would be glad to answer any queries thereon at the next meeting.

The meeting then closed.

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* *Trans. Fed. Inst.*, vol. v., page 462.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE ROOMS OF THE CHRISTIAN INSTITUTE, GLASGOW,
OCTOBER, 11TH, 1893.

MR. J. B. ATKINSON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected by ballot:—

FEDERATED MEMBERS—

Mr. WALTER G. ANDERSON, 55, Sardinia Terrace, Glasgow.
Mr. HUGH CALDWELL, The Braes, Bridge of Weir.
Mr. ARCHD. D. COWIE, Alma Vale, Airdrie.
Mr. JOHN CUTHBERTSON, Thomson Street, Kilmarnock.
Mr. WILLIAM GARVEN, 14, Lorne Terrace, Maryhill.
Mr. JOHN MORTON, Ellismuir Colliery, Baillieston.
Mr. GEORGE ROBIN, 30, Corunna Street, Glasgow.
Mr. THOMAS STEVENSON, Eddlewood Colliery, Hamilton.
Mr. JOHN B. THOMSON, Fairview, Hamilton.

NON-FEDERATED MEMBERS—

Mr. SAMUEL BURNETT, Pirnie Lodge, Slamannan.
Mr. JOHN GARDNER, 9*a*, Hopetoun Street, Bathgate.
Mr. JOHN SHAW, Ferniegair Colliery, Hamilton.

DISCUSSION UPON MR. J. S. DIXON'S "NOTES ON WORK DONE BY THE STANLEY HEADING-MACHINES AT HAMILTON PALACE COLLIERY.*

Messrs. STANLEY BROTHERS wrote that Mr. Dixon remarked in his paper that while the Stanley heading-machine drove the headings four times faster than hand labour, the cost was about double that of hand labour. It would appear that the excessive cost of headings, as driven at the Hamilton Palace colliery, is due partly to the fact that an unusually large, and, in the opinion of the writers, an unnecessary number of men were employed in working the machine. The usual number of men

* *Trans. Fed. Inst.*, vol. vi., page 4.

engaged is three: one at the front of the machine, whose duty is to pass back the coal and slack ; one driving the machine and assisting the man at the front; and a third employed in filling the tubs. The machines have been in use at the Nuneaton colliery for six years, and in no case when driving on the level, or to the rise, were more than three men employed, and the distance driven per shift was quite as much as at the Hamilton Palace colliery. When driving at a considerable dip it was found advisable to have a fourth man to assist in loading. That three men are sufficient under ordinary circumstances for the satisfactory working of the machine has been abundantly proved at collieries in various districts. If, as in other collieries, Mr. Dixon had found it practicable to work the machine with three men, the cost would have been reduced to 1s. 6d. per ton, as compared with 2s. 6d. per ton, the actual cost of driving. The writers are of opinion that the system Mr. Dixon has adopted is not the cheapest method of driving headings (11 feet wide); as by the system adopted, it really amounted to driving a separate 5 feet heading with each machine, so that no advantage was gained by having a greater space for the men to work in. A more satisfactory system would have been to use two machines (right and left handed) coupled together by stays and braces at the top and bottom. The men would then have had the advantage of a space of 11 feet in front of the machine in which to work, and there would have been more than 4 feet between the coupled machines in which to pass back the material, or through which to advance the tubs, and load them direct from the face. It may also be mentioned that the No. 4 pattern, 5½ feet double machine would cut a heading at one operation in two circles, touching each other in the centre, leaving only a little coal (at the top and bottom), which could be removed by hand labour with the utmost ease. The double machine could be worked by 5 men: 1 at the machine, 2 at the front, and 2 filling (or with the conveyor attached for carrying the coal behind the machine, 4 men would be quite sufficient); and greater speed would have been obtained than with a single machine, as less time would be required to fix and anchor it in the heading. A machine of this type and size would produce, say, 27 tons per shift, an estimate based upon the rate of progress mentioned by Mr. Dixon ;* and taking the wages of the 5 workmen at 5s. per shift, the cost of coal would be 11d. per ton, or considerably less than the cost of hand labour. By the use of two double machines, and of a small machine to drive the thirls, the two main roads could be driven continuously, and the serious loss of time entailed in moving the

* *Trans. Fed. Inst.*, vol. vi., page 8.

machines from one heading to another would have been avoided, a loss which unquestionably added considerably to the cost of driving the roads at the Hamilton Palace colliery. Mr. Dixon remarks that the exhaust air was found insufficient to keep the heading clear of fire-damp, but this difficulty has seldom been encountered in the working of the Stanley heading-machine, and in only two cases has any complaint been made. In one case, upon investigation, it was found that the exhaust air was so much denser than the warm air mixed with the fire-damp that it settled and travelled back on the floor of the heading, naturally leaving the fire-damp untouched above it. Where the proportion of large coal is of little importance, as in the case of collieries making coke, or where there is urgent necessity for rapid driving, the full-cut heading-machine is strongly recommended, as not only can much greater speed be obtained (say an average of 3 feet per hour) but the cost of driving is far less. A single 5 feet heading-machine, producing 2 tons of coal per yard, would drive 24 feet per shift with 3 men, the slack being automatically removed from the face of the heading and delivered behind; hence 16 tons would be wrought for 15s., or at the rate of 11¼d. per ton. In conclusion, the writers desire to acknowledge the perfect fairness and impartiality of Mr. Dixon's paper, but join issue with him as to the relative cost of driving by machine and hand labour, even in as wide a heading as 11 feet, and trust they have satisfactorily proved that whatever may have been the cost at Hamilton Palace colliery, the general experience is that machine-driving is cheaper than hand labour.

Mr. J. M. Ronaldson (Glasgow) said, in reference to Mr. Dixon's statement that the exhaust air was insufficient to cope with the fire-damp, he might state that at Trabboch colliery the same difficulty was experienced, and it was not a very fiery colliery. Where there was any fire-damp he did not think any one should attempt to ventilate headings simply with the exhaust air from the machine.

Mr. Thos. Arnott (Newton) asked if Mr. Ronaldson's remarks referred to all sizes of the heading-machine?

Mr. Ronaldson replied that his remarks applied to the 5 feet heading-machine.

Mr. Arnott suggested that a much larger one might not be liable to the same objection.

Mr. Ronaldson said that no doubt a size of machine could be reached, from which enough compressed air might be exhausted to make the ventilation satisfactory, but, with a 5 feet machine, no one, in such circumstances, should attempt to ventilate the heading with the exhaust air alone.

Mr. Dixon, replying to Messrs. Stanley Brothers' remarks, said that he gave in his paper his experience of working the heading-machines for five years; and, having cut 7,600 yards of a 5 feet place, he thought that experience was a fairly prolonged and exhaustive one. The circumstances of other collieries might be different in many ways. The wages might be more, or less, or the workmen more expert. At the Hamilton Palace colliery 3 men are generally employed at each machine, at times 4 and 5 men worked two machines. In the trial mentioned in the paper when 5 men were employed a fourth more heading was cut than usual. He could assure Messrs. Stanley Brothers and the members present that he adopted all possible means of keeping down the cost. His workmen were efficient in handling the heading-machines. The cutting was let by contract, and the workmen had every inducement to work well. He thought that the full cut heading-machine was made at his suggestion, but when tried at the Hamilton Palace colliery it was found to be impossible to keep the machine up to the face. What he wanted was rapid progress, he did not much regard the results in the matter of large and small coal, and he was compelled to return this machine, which might since that time have been perfected to a considerable degree. He found that it was impossible to drive one place 5 feet in diameter. He found that the exhaust air was insufficient to ventilate the heading, and members would agree with him when it was remembered that the heading-machine only worked for a short time during each shift. For example,* he had shown that out of 8 hours and 14 minutes of work, the machine was only at work for 1 hour and 18 minutes, so that there would be complete stagnation of the ventilation for 7 hours. To obviate that difficulty he used a blower in the shape of a 1 inch air pipe, blowing air into the working-place. This system was found to be insufficient, and he had no other option but to adopt the mode of working described in his paper. Messrs. Stanley Brothers stated that a 10 feet machine could be driven at the same cost as a 5 feet machine, but of this he had no experience. The heading-machine, in his experience, cost in driving about double the rate of hand labour, all outlays for cutting, removing the coal, laying pipes, and shifting the machines included; nevertheless, in such a field as that at Hamilton Palace colliery, where the disadvantages were very great, he would have no hesitation in adopting their use for its rapid development.

Mr. Archd. Blyth (Hamilton) referring to the remark that Scotch workmen were not so expert as Englishmen, said an expert was sent to instruct the workmen at Hamilton Palace colliery; and, when they started their own workmen, they cut 2 feet per day more than he did.

* *Trans. Fed. Inst.*, vol. vi., page 8.

The PRESIDENT said that the subject of the application of machinery to the working of coal in any form was a very important one. As there were no further remarks, the discussion would now close, and he proposed that the hearty thanks of the meeting be given to Mr. Dixon for bringing the subject before them.

Messrs. STANLEY BROTHERS wrote that a full-cut heading-machine was at work prior to the suggestion made to them by Mr. J. S. Dixon.

The vote of thanks was then agreed to.

DISCUSSION UPON MR. JAMES HAMILTON'S PAPER "ON THE REPORT OF THE ROYAL COMMISSION ON MINING ROYALTIES."*

Mr. BARROWMAN (the Secretary) said the members were indebted to Mr. Hamilton for placing before them, in the compact way he had done in his paper, the substance of the very voluminous report of the Commission on the important subject of mining royalties. In view of the wild statements made of recent years as to the rates of royalty it was satisfactory to have placed before them† a statement of the royalties in the various districts, from which it appeared that the highest royalty for coal in Scotland was 1s. 3d.,‡ and the average about 7d. per ton. As to the separation of ownership of surface and minerals, under old Scotch law and practice,§ it was worth while bearing in mind that the minerals referred to in the old Acts of the Parliaments of Scotland were chiefly, if not exclusively, the precious metals. The speaker had drawn attention to this fact in a paper on "Scotch Mining Legislation."‖ The Acts never included coal under the general designation of minerals. When coal was dealt with, it was referred to in express terms. In considering the systems of letting minerals it should be borne in mind that modern mining leases are the result of several hundred years of mining experience, and it was interesting to observe the various steps of progress towards the present system of fixed rents, with alternative royalties in the proprietor's option; illustrated in the following instances of leases in various parts of Scotland. In a lease of coal in 1572, the tenants were bound to pay a fixed annual rent, and were restricted to "ane eye and ane coilpot with six heids thereintil." In leases dated 1611 and 1629, a fixed rent was stipulated, the tenants being allowed to employ what number of coal-hewers they chose. Leases

* *Trans. Fed. Inst.*, vol vi., page 9. † *Ibid.*, page 11.

‡ In the *Third Report*, question 13,124, it is 1s. 4d. per ton. § *Ibid.*, page 12.

‖ *Trans. Min. Inst. Scot.*, vol. x., page 32.

of 1661, 1681 and 1723, contain a stipulation for fixed rent, and limiting the number of coal-hewers and their bearers or hurlers. A lease, dated 1724, imposes a penalty in the event of more than the stipulated number of colliers being employed. Additional rent for each person employed beyond the specified number was provided in a lease dated 1734. Leases of various dates between 1755 and 1845, provided, in addition to the fixed rent, for a lordship in the proprietor's option of a proportion of the selling price on the pit-head, the rate being usually $\frac{1}{8}$th, sometimes more, and sometimes less where water had to be pumped or the working was otherwise impeded. Sometimes there was a varying scale of $\frac{1}{8}$th to $\frac{1}{11}$th, according to the depth under water-level. Later, a fixed tonnage rate was stipulated, sometimes for coal only, no rate being put on dross, because it was the custom to leave the dross in the workings of the mine. Then a rate for coal and dross, separated by a screen of specified dimensions, was the practice, and is so to a great extent still. Of late years, and especially since coal-cleaning has come into vogue, a uniform rate for the whole produce (great and small) has found favour. In some instances the old method of payment of a proportion of the selling price has been adopted recently. In certain districts, especially where the seams are thin, the lordship is at a rate per acre, sometimes graduated according to the thickness the seam may be found in course of working from year to year. Concurrently with these successive steps in the arrangement of fixed rents and royalties, the conditions of abandonment at an earlier period than the stipulated date of expiry of lease give evidence of progress. Among the earliest of these conditions which, although not strictly involving abandonment, was of similar effect, was the suspension of the fixed rent in the event of war or pestilence. Later, it was provided that the lease should terminate in the event of the coal wearing out; then in the event of the coal being wrought out or unworkable at a profit. Later still, the tenant had the opportunity of a break at every five or seven years of the lease as well as when the coal was wrought out or unworkable to profit; while of recent years the general practice is to have power to take advantage of a break every three years. Under existing arrangements a tenant of a coal-field in Scotland may take advantage of any break; he has the benefit of a short clause to tide over a period of depression, or of small output; and if he abandon the lease he can get as much for his plant and buildings as the proprietor could get, while the proprietor is bound for the whole period of the lease. Before the Commission met there was considerable clamour about accumulated shorts, some isolated cases of hardship being held up as an example of the greed of proprietors and the pitiable condition of

coal-owners. The evidence laid before the Royal Commission showed that the principal cases of shorts (or overpaid rents as they are also called) are those where areas, additional to the original leasehold, had been leased, with no immediate prospect or intention of working them. If a coal-owner takes a mineral field in excess of his requirements, or in anticipation of what he may require years hence with the view of getting a larger return for his outlaid capital, or of keeping competition out of his neighbourhood, he cannot expect the proprietor to let him hold the field without payment of rent, he meanwhile doing nothing to develop it. His possession prevents the proprietor letting the field to any one else, and so a rent must be paid for what he chooses meantime to keep unproductive, and a considerable sum in shorts may thus accumulate. It may be fair or it may not be fair to give a lessee an unlimited time (within the currency of his lease) to make up such shorts. The particular circumstances of each case must be known before this can be determined. Shorts may accumulate through the voluntary delay of the tenant to work the field for which the rent is payable, or through the tenant's want of capital to work the field properly, or through mismanagement. In any of these cases the apparent hardship arising from the accumulation of shorts and inability to wipe them off is clearly not a matter requiring redress at the proprietor's hands. When the mineral field of a proprietor, by being leased to another, passes out of his control, he is entitled to have it developed according to the best system, and for that purpose to have it sufficiently equipped and efficiently managed. Perhaps Mr. Hamilton will explain the statement he made* in connexion with the respective interests of lessor and lessee in the taking of a mineral field. "To the lessee the determining factor is the area." Although a lessor may desire a fixed rent which may be expressed as at a certain rate per acre, it is what the field is likely to yield that after all is the determining factor with him as with the lessee. As to restriction of the power of a tenant to assign his lease, the very general custom in Scotland of excluding assignees unless with the proprietor's consent is founded on good reason. Occasions arise, especially in good times of the trade, when an unscrupulous lessee could dispose of his interest at a sum far exceeding its value, might even include in that sum the capitalized value of an increase of royalty to the end of the lease, and through the turn of trade or other unforeseen circumstances the concern might become so burdened with capital as to be unprofitable to the assignee. In these days of limited liability companies the risk of such practices is greater than formerly. It is the proprietor's interest, and it is only fair that he should

* *Trans. Fed. Inst.*, vol. vi., page 15.

have the power, to veto such transactions. In all limited liability companies there is of course a kind of assignation constantly taking place through the transfer of shares, which, if sold at a time of good trade and at a premium, may bring about the state of matters already referred to, through no effort towards that result on the part of the tenant, and outwith the control of the proprietor. The enquiry by the Royal Commission has served to clear away much misapprehension and confusion of ideas as to wayleaves; and to emphasize the fact that payment of wayleave is not a matter in which the public, or as a rule even the lessee, is concerned, but only the proprietors granting and getting the wayleave. The consequences of refusal of a wayleave can very rarely indeed become a public question. Before the public are likely to be materially affected thereby the interests of the parties more immediately concerned will have found a solution, or the public interest will have got a way of access authorized by Act of Parliament. The power which the law, as now interpreted, gives the surface proprietor to prevent the subjacent mineral proprietor from lowering the surface of the ground, and that altogether irrespective of the value of the surface, is certainly greater than was contemplated when severance of the properties took place. And, as Mr. Hamilton points out,* this presses sometimes so hard on the mineral proprietor as to make his property valueless; for there are some seams that could not be worked to profit except by a system of complete excavation, necessarily involving lowering of the surface. The mineral proprietor's only resource in order to work, is to buy the right to lower the surface on the best terms he can from the surface proprietor. This presses hard on the mineral proprietor, and the Commission recommends a measure of relief; but, like wayleaves, this matter does not concern the public, nor, as a rule, the lessee of the minerals, who, if the burden of payment falls on him, pays a correspondingly smaller rate of royalty for the coal worked. In the case of White *v.* Dixon, which set forth the law of the respective rights of the surface and subjacent mineral owners, perhaps more clearly than had, up till the date of that decision, been done, the Lord President of the Court of Session speaks of longwall working as a thing entirely unknown in 1800. If this influenced the judgment in the case, it is unfortunate that the evidence on the point was not fuller and more accurate. It is certain that the longwall system of working was in use at Kinneil as early as 1765, having been introduced there by Dr. Roebuck, the then tenant of that colliery, who imported colliers from Shropshire to work by that method. Further, in a report, dated 1793 by

* *Trans. Fed. Inst.*, vol. vi., page 21.

Messrs. Grieve and Taylor, upon the minerals in the track of a projected canal between Edinburgh and Glasgow, reference is made to workings at Cleland and to a certain seam of coal "used for buildings in the Shropshire way of working." It seems then that longwall was known and to some extent practised in Scotland before the beginning of the present century. As to Mr. Hamilton's remarks on the statement made by Lord Blackburn that "the stoops were left with the intention of supporting the surface permanently,"* no doubt the pillars left in many cases were not sufficient to maintain, and did not maintain, the level of the surface permanently; but this was probably owing to the pillars having been inadvertently left too small as the workings were carried to the dip: or to unauthorized robbing of the pillars. At all events it seems clear that, in the framing of many of the leases of coal in Scotland, up to the introduction of the modern method of extracting the pillars, it was the intention to uphold the strata above the whole workings. This does not necessarily infer that the maintaining of the surface of the ground was in view. Most probably the primary object was to uphold the roof and so save the workings from collapse during the continuance of the lease, or so long as necessary for the safety of the colliery. [Mr. Barrowman here read extracts from a number of leases to illustrate this point.] Prof. Sorley and others who gave evidence before the Royal Commission have done good service in showing the fallacy of the pet statement of the agitators, that the exaction of royalties keeps down wages, cripples industry, and places this country at a disadvantage in the markets of the world. If, as Prof. Sorley clearly indicated, the abolition of royalties would do the workmen no good, on the other hand it was probable that the general adoption of a sliding scale of royalty proportionate to the selling price, so strongly advocated by some coalowners as likely to afford them relief in times of depression, would be no less illusory. At present, a coal-owner who is on the sliding scale may derive a benefit when low prices rule, in having a royalty rate low in comparison with that of a rival coal-owner whose rate is a fixed one; but if all were on a sliding scale this advantage would disappear, because in times of dull trade each would use the reduction of royalty afforded by the sliding scale to reduce selling prices. This would be a slight advantage to the public, but none to the individual coal-owner. Although recent agitation has revived to some extent the old system of payment of royalty by a proportion of the selling prices, it is doubtful if coalowners will seek for its general adoption, especially, as has

* *Ibid.*, vol. vi., page 21.

been pointed out by Mr. Hamilton, it involves the examination of their books by the proprietor and criticism of details of their commercial management.

Mr. HAMILTON, in reply to a member, said the "ton" referred to in the tables in his paper was the imperial ton of 20 cwts.

Mr. DIXON said, in reference to Mr. Barrowman's remarks as to preserving the surface, that the quotations from the leases showed that the stoops were left to preserve the workings. Those ancient people were indifferent to what took place on the surface. The effect of one quotation Mr. Barrowman read was to preserve the "heugh"—that was, to preserve the pit. Another read by him was to "form a permanent support to the roof." That had nothing to do with the surface. It was with the preservation of the mine. He thought the object of their forefathers was purely to preserve the mine, and that they were comparatively indifferent to the surface. He had been in many old workings, and the stoops were of so small a size that it was quite impossible that they could stand for any length of time so as to preserve the surface. In the west end of Glasgow, the coal was worked very extensively, and the subsidences were giving rise to some damage at the present time. The places there, in his experience, were about 20 feet wide, and the stoops 6 and 7 feet square. To his idea, they worked in that way as long as they could, and when the workings began to collapse they sank another shaft. At Hillhead, where the damage referred to was taking place, the old pits were very numerous. He had once seen an old plan—a most interesting document—which showed that the whole of the district was a mass of old shafts. There was one every 200 or 300 yards.

Mr. BARROWMAN said his impression was that those leases proved that it was not merely the principal roads but the whole of the workings that were to be preserved.

Mr. DIXON said, as bearing on the point, Mr. Barrowman brought out cases where the surface belonged to one person and the coal to another, and where the lease did not tend to the upholding of the surface but the upholding of the roof.

Mr. HAMILTON, replying, said that Mr. Barrowman's remarks were more supplementary than critical, and that his quotations from old leases were exceedingly interesting. His antiquarian instincts might find a very useful outlet in a paper on "The Evolution of the Mineral Lease." It was quite true that in the evidence, the cases of shorts involving the largest sums, are those where the intention of the lessee in taking the field was for some ulterior purpose, such as to restrict competition, or for

better security for capital outlay, and as such did not call for redress at the hands of the proprietors. But it is not uncommon for shorts to accrue through no fault of the lessee. The recommendation of the Royal Commission was that in every case before he could have an extension of his lease to work up shorts or repayment thereof, he should require to prove to the satisfaction of the court that they had not accumulated owing to his default. It would have been a more accurate use of language if in the statement that to the lessee the determining factor of fixed rent is the area of the leasehold "quantity of mineral" had been substituted for area. But in a general way, the area represents the quantity of mineral in cases where a comparison of fixed rents is possible, and as it stands it showed quite fairly what was intended—that on this point the negotiating parties were influenced by strongly conflicting considerations. On severance of ownership of land and minerals, it was only necessary to remark that cases had occurred where a lessee has had to choose between bearing the unforeseen burden of a payment to the surface proprietor or the sacrifice of capital laid out; and to emphasize the objection to the recommendation of the Royal Commission which placed the obligation of settling with the surface-owner upon the mine-owner, in the phraseology of the report that means the lessee, or the person who works the coal.

Mr. Barrowman asked, with reference to a case cited by Mr. Hamilton where the tenant was bound to pay for leave to lower the surface, if it was not a case where the coal had been let before the present state of the law was clearly enunciated?

Mr. Hamilton answered in the affirmative. He then argued that this burden should be put on the landlord, for he had let to the tenant certain coal which could not be worked under his limited rights to the coal; and the Royal Commission put it on "mine-owners," which meant the lessee or the men who worked the coal.

Mr. Barrowman did not think that there was anything very special in that objection, because in any future arrangement between landlord and tenant the latter would pay a less royalty corresponding to the amount paid for leave to lower the surface.

Mr. Hamilton said it would be hard for the tenant to discover after the lease was entered into that the matter was so limited.

The discussion was then adjourned.

Mr. Robert Martin then read the following paper on "The Mid-Lothian Coal-basin:"—

THE MID-LOTHIAN COAL BASIN.

BY ROBERT MARTIN.

The Mid-Lothian coal basin is oblong in shape, extends, roughly speaking, north and south from the Firth of Forth at Musselburgh, and contains an area of over 50 square miles.

The collieries on the eastern outcrops are Wallyford, Carberry, Cowden, Newbattle, and Arniston, and on the western outcrops, Penicuik, Loanhead, Gilmerton, and Niddrie (Fig. 1, Plate IX.).

The East-Lothian and Fife coal-fields are continuations, the former over the Roman Camp Hill, the latter under the waters of the Forth. It is conjectured that the Mid-Lothian coal-beds were once connected to the coal-fields of West-Lothian and Stirling; the intervening area having since been denuded by diluvial action. If this be so, these coal-basins may be described as detached portions of the central coal-field of Scotland.

On the western side of the basin the coal-strata dip from 50 degs. inclination to vertical, and at one place they overhang, the pavement of the seam being over the miner's head. The bottom of the basin is comparatively flat, with a long easy rise to the eastern outcrops.

Owing to irregularity of stratification, seams a short distance apart have very different angles of dip. Fig. 2 (Plate X.), shows No. 11 pit Niddrie and the adjacent strata at almost every variety of inclination. At Loanhead (Fig. 3, Plate X.), the great seam dips at 58 degs., behind it in the oil-shale measures, the Pentland shale seam begins at the surface at 19 degs. inclination, never exceeding 35 degs. till a depth of 800 yards on the slope is reached.

The incidence of these edge seams is probably due to slow subsidence against the steep sides of the basement-beds. At the almost rectangular bend (Figs. 3 and 6, Plate X.), the strata are not broken as if they had been tilted suddenly from beneath by eruptive forces.

The general opinion as to the origin of coal-beds seems to be that they are the result of pressure and chemical action on masses of vegetation, which either grew or were drifted into their present sites. The daugh or fire-

clay, usually found under coal, is supposed to be the soil or land-surface on which the ancient forests had their roots. In either case, whether of growth or of drift, the vegetable matter was submerged by a constant and steady sinking of the area on which it rested, and covered over with successive layers of mud, sand, calcareous matter, etc., as we now find it.

The Appendix (page 392) shows the general succession of the seams in the basin. On the northern side of the Sheriffhall fault the upper measures are as indicated. On the southern side, the upper seams are awanting. The coals shown as greymechan, salters, etc., are worked in Polton and Whitehill under other names, viz., great seam, rough, splint, and jewel.

The Carboniferous Limestone coals are the most extensively worked in the basin. The section (Appendix) shows the names of the seams as they are known at Niddrie, Newbattle, and Loanhead collieries. A stratigraphy of the two latter places is now nearly possible and would be interesting. They are exactly opposite each other and have been extensively worked. The parrot of Loanhead colliery is above the great seam, that of Newbattle colliery is down immediately above the No. 3 limestone, and neither appears to extend across the basin.

The oil-shale measures shown on the section (Appendix) are those of Pentland mines, the only part of the basin where they have as yet been worked.

The most striking feature of the Carboniferous Limestone strata is their great variety in thickness. They appear to be most numerous on the western side. They are deepest and most fully developed in the northern part of the basin, and all the coals thin away to the south.

The seams of coal worked at Niddrie colliery are: south parrot, great seam, stairhead, carlton, and north greens.

The north greens seam has been worked all along the western outcrop, but not, so far as the writer knows, on the eastern side. It contains parrot at Niddrie and Gilmerton, but none farther south.

The carlton seam is worked at Niddrie and, perhaps, at Loanhead mined under another name.

The corbie craig is a very persistent seam on the western side and has been extensively worked from Niddrie towards Brunstane.

The great seam is the best known and most extensively worked of the series. It has been proven and worked at all the collieries. It contains parrot, but the area of workable parrot is confined to Niddrie and across the basin to Cowden; at both these places it thins away to nothing on the north and south sides.

The following table shows the section of the great seam at various

points on the west side, and is an example of the thinning referred to toward the south:—

Niddrie.	Ft.	In.	Gilmerton.	Ft.	In.	Loanhead.	Ft.	In.	Penicuik.	Ft.	In.	Brunstane.	Ft.	In.
Coal ...	0	3	Coal ...	0	10	Coal ...	1	0	Coal ...	1	0	Coal ...	2	0
Parrot ...	2	3	Parrot...	0	5	Shale ...	0	6	Fireclay	0	9			
Ironstone	0	8	Coal ...	1	2	Coal ...	2	0	Coal ...	0	9			
Shale ...	0	3	Parrot...	0	3	Parrot...	0	4	Fireclay	2	6			
Coal ...	1	6	Coal ...	1	8	Coal ...	1	3	Coal ...	2	6			
Coal ...	2	6	Fireclay	0	3	Fireclay	0	3						
			Soft Coal	3	0	Coal ...	1	3						

The south parrot is worked at Niddrie and maintains its form as far south as Loanhead, but there it is only 4 inches thick. The Loanhead parrot and ironstone is a few fathoms above the great seam, and is named in old reports as perch or rumbles. There is a rumbles at both Gilmerton and Niddrie, but there is no parrot in it. The Penicuik ironstone is immediately above the great seam, and seems to be the Loanhead parrot-and-ironstone without the parrot.

The seams worked on the eastern side lie between the third and fourth limestones, and are known as parrot, kailblades, splint, coronation, and great seam in ascending order.

The present output from the whole basin is about one million tons per annum. If the area from Musselburgh to Temple, about 25 square miles be taken, any five of the under seams with an aggregate thickness of 6 yards will more than maintain that output for the next three hundred years.

The only intrusive fault is known as the the Niddrie whin dyke. It cuts across the strata, but does not disturb or change them. It is 60 feet wide, and is believed to extend from Arthur's Seat, the trap of which in one part of the hill is similar to it in texture.

The Sheriffhall fault is a downthrow to the north of 480 feet, and seems to mark a good many changes on both sides.

There are large areas remarkably free of faults, others again very much disturbed.

In all the edge seams the faults are, as a rule, nearly at right angles to the outcrop, and parallel to each other. The writer has seen no fault or even a small hitch across the hill.

The horseshoe at Gilmerton is, if not a fault, certainly a freak of nature. The No. 1 limestone bends round there into a loop or horseshoe shape. The north greens coal and No. 2 limestone only curve

slightly inwards and continue on in their course. Yet, within the loop these two beds are found forming a small separate basin by themselves.

The double bending in the shale measures at Pentland is even more puzzling. The strata there are folded over and over like cloth.

The method of working is mostly longwall. Fig. 4 (Plate X.), shows the longwall workings in Niddrie south parrot seam. The coal is lowered from the upper levels by means of a carriage and a back-balance attached to $\frac{3}{4}$ inch plough-steel wire-ropes working on a drum. The winding is done in vertical shafts or on inclines, and sometimes both combined, as shown in Figs. 2, 3, 5, and 6, Plate X.

Pumping is done by direct-acting compound condensing steam pumps. The loss in steam pressure at the lowest point in Niddrie is 3 lbs. At Penicuik, a Moore hydraulic pump has taken the place of steam pumps and is giving great satisfaction (Fig. 6, Plate X.)

Ventilation is effected by exhaust and forcing fans. Though the workings in this basin are perhaps the deepest in Scotland, there is very little fire-damp. The structure of the basin with the open outcrops may account for this.

APPENDIX.

NAMES OF THE VARIOUS COAL-SEAMS, ETC., OF THE MID-LOTHIAN COAL-FIELD.

Name of District.	Musselburgh.	Newbattle.	Loanhead.
Upper Coal-measures.	Clayknowes coal.		
	Splint coal.		
	Rough coal.		
	Beefie coal.		
	Jewell coal.		
	Greymechan coal.		
	Salter's coal.		
	Nine feet coal.		
	Fifteen feet coal.		
	Four feet coal.		
	Seven feet coal.		
Millstone Grit.	Grey and red sandstone.		
Carboniferous Limestone.	No. 6 limestone.		
	No. 5 limestone.		
	South parrot.		South parrot.
	No. 4 limestone.		
	Wood coal.	Deception.	Flex.
	Flakes coal.	Cryne.	
	Rumble coal.	Mavis.	Parrot-and-iron-stone or rumbles.
	Laverock coal.		
	Great seam coal.	Great seam.	Great seam.
	Stairhead coal.	Diamond.	Stairhead.
	Gillespie coal.		Charlie's coal.
	Little Gillespie coal.		
	Corbie Craig coal.	Siller Willie.	Moffatt's coal.
	Stinkie coal.		Gillespie.
	Little splint.	Coronation.	Black Chapel.
			Perpetual.
	Peacocktail coal.	Smithy coal.	Kittlepurse.
	Real Corbie coal.	Splint coal.	Stinkie.
			Corbie Craig.
	Carlton coal.	Kailblades.	South coal.
	Blue coal.	Parrot coal.	North coal.
	No. 3 limestone.		
	Vexhim coal.		
	No. 2 limestone.		
	North greens coal.		North greens coal.
	No. 1 limestone.		
Oil-shales.	Paper shale.		
	Houston coal.		
	Fells shale.		
	Broxburn shale.		
	Straiton sandstone.		
	Pentland shale.		
	Burdiehouse limestone.		
	Shales.		

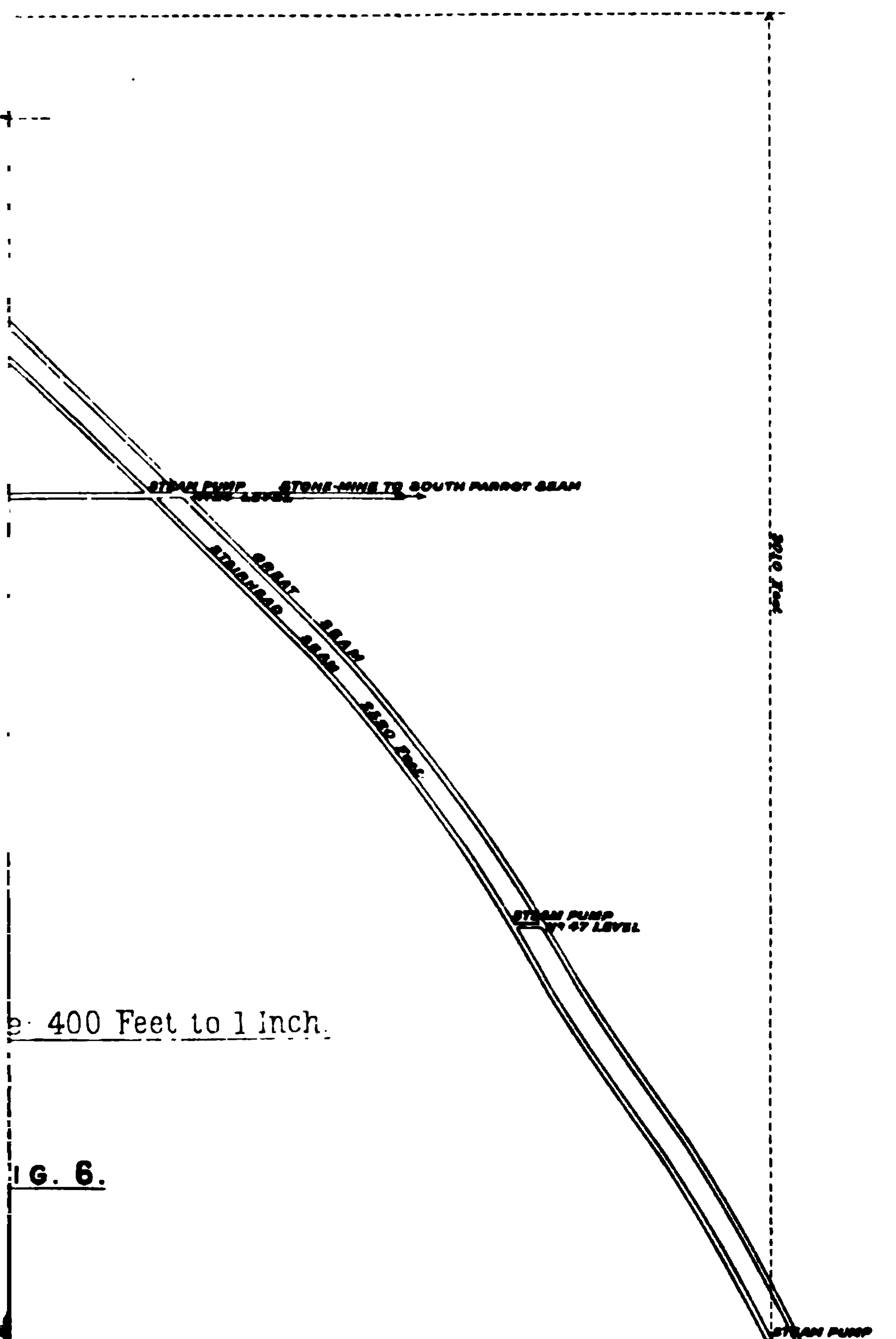
Mr. JOHN HOGG then read the following paper on "Coal-washing at North Motherwell Colliery:"—

Mining Inst
Transa

n Coal-basin."

FIG

FIG. 5.



e 400 Feet to 1 Inch.

IG. 6.

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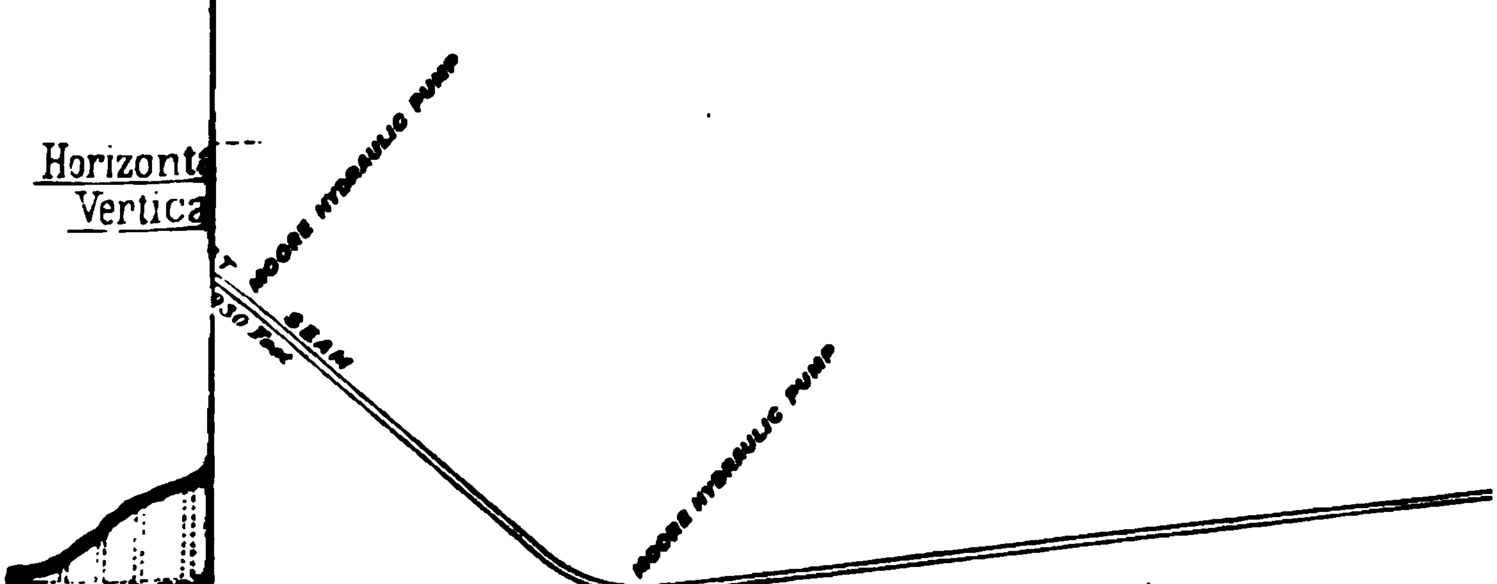
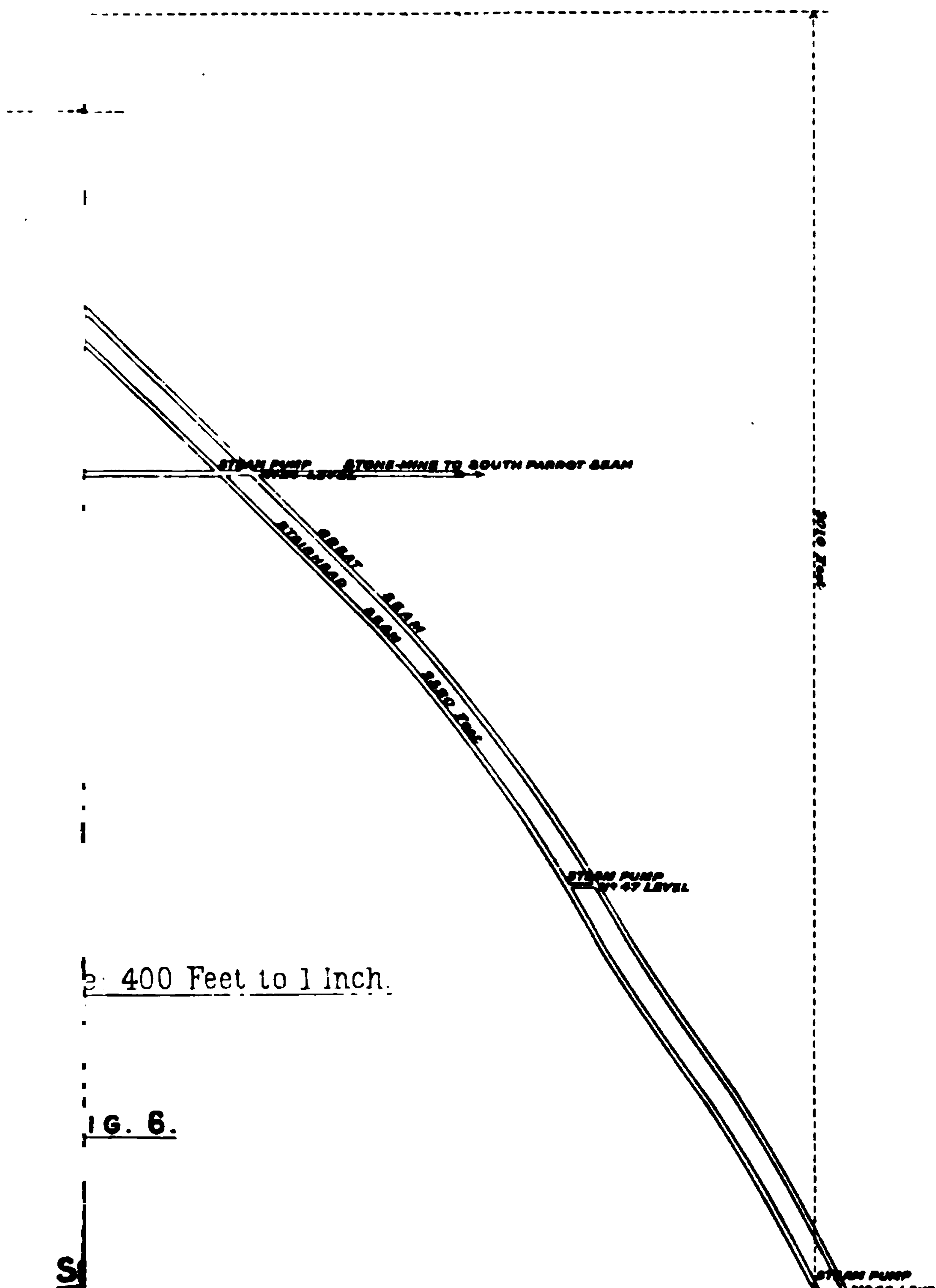


Fig

Fig. 5.



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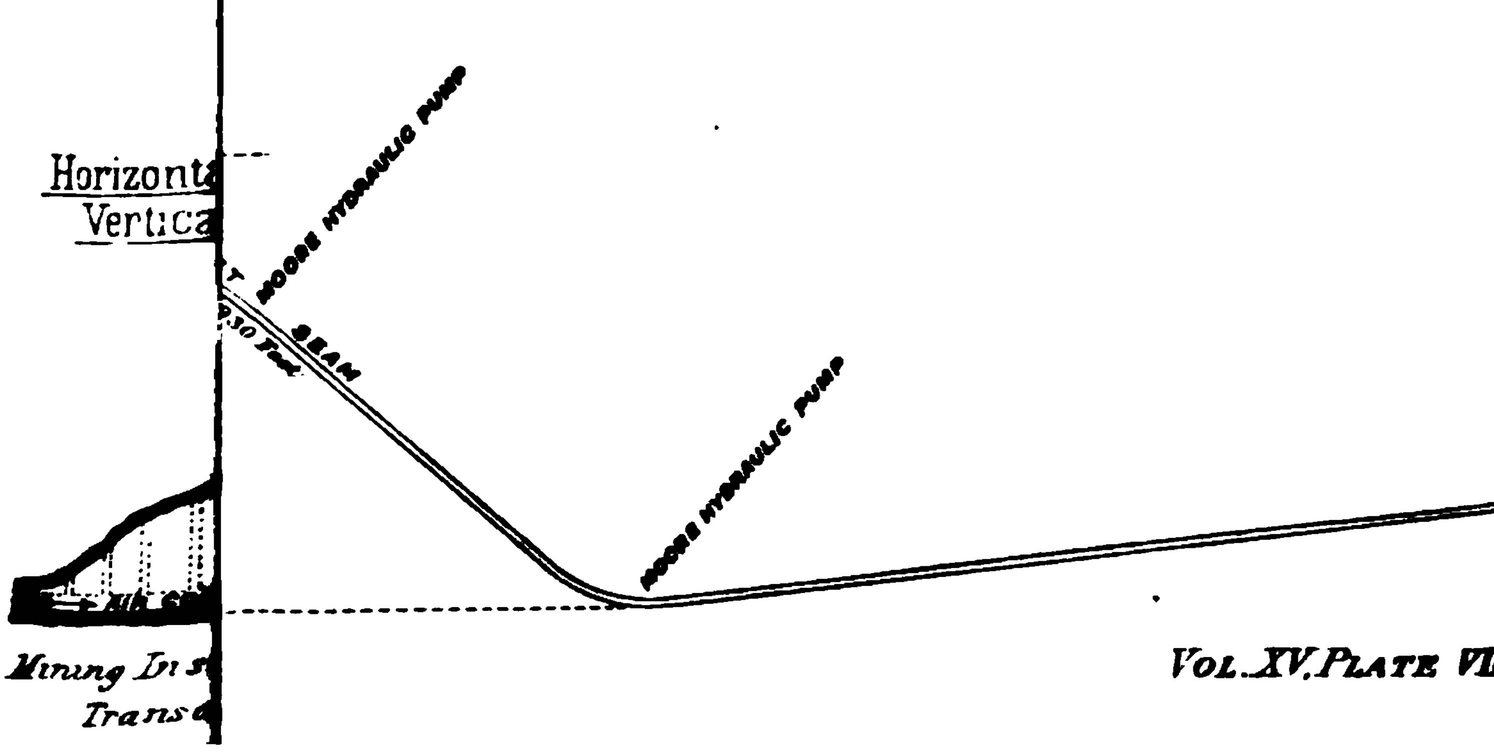


COAL-WASHING AT NORTH MOTHERWELL COLLIERY.

By JOHN HOGG.

The Lührig coal-cleaning plant is erected in a position suitable for receiving and treating the output from three pits, the coal being hauled by means of an endless-rope to the screening-platform *a* (Figs. 3, 4, and 5, Plate XI.). The hutches are there run into revolving tipplers which deposit the coal on perforated vibrating-screens *b*. The lump coal is passed on to picking-tables for dry-cleaning, and separating into sorts for the market. The small coal falls into the raw coal-hopper *c* (Fig. 3), whence it is elevated by the main-elevators *e*, and delivered into the large revolving-screen *d* situated in the top-floor of the washery-buildings. The raw coal or dross-hopper has capacity for nearly 100 tons. The main-elevator buckets carry 60 lbs. each, and travel at the rate of 47 buckets per minute. The sizing-drum is constructed of perforated steel-plates, and consists of three shells dividing the dross into four sizes, viz., treble nuts, double nuts, single nuts, and gum. It revolves 12 times per minute.

The various sizes of nut coal are conveyed by spouts into separate jiggers *f* (Figs. 3, 5, and 6, Plate XI.) of which there are seven; two for trebles, two for doubles, two for singles, and one for the crushed product from the roller mill *i* (Fig. 6). In these jiggers, the fine rubbish falls through perforated plates fixed near the bottom of each box, and is run direct into the refuse-pit. The larger pieces of rubbish are conveyed by means of a worm, working in front of the jiggers, to an elevator at the side of the washing-boxes, thence through the rolls and into the jigger for the crushed products. The refuse from the latter jigger is discharged by the elevator *k* (Fig. 5) into a channel leading to the refuse-pit. The clean nut coal from the jiggers is delivered over vibrating drainers *g* (Figs. 5 and 6), and is there rinsed with clear water and run into hoppers *h* (Fig. 6) ready for loading into trucks. These hoppers can store 80 tons of nuts.

The fine or gum coal from the revolving-screen passes with the overflow water from the nut coal-jiggers into a grader *m* (Figs. 3 and 6). The grader is a series of pyramid-shaped boxes into which the current of water deposits the coal in different sizes according to its gradually decreas-

ing velocity. These boxes supply through apertures in the bottoms of the pyramids the fine coal-jiggers *n* (Figs. 3, 5, and 6). These jiggers are provided with felspar-beds resting on perforated plates. The dirt separates in these washers through the felspar to the bottom of the machine, and is delivered into the refuse-pit. The elevator *o* (Figs. 5 and 6) raises the refuse collecting here from all the machines, and discharges it into bogies for the waste-heap.

The clean coal from all the fine coal-jiggers is carried with the overflowing water from these machines to a small draining-drum (Figs. 2, 3, and 5, Plate XI.) made of copper sheets with very small holes which separates the pearl coal from the finest coal. The pearls are lifted by an elevator *p* into large storage-hoppers *q* (Figs. 2 and 5) having capacity for 350 tons. The finest coal from the small drum passes with the dirty water into the sludge-recovery apparatus *r* (Figs. 2, 3, and 6) which works in a long pit underneath the fine coal-jigger floor, and consists in the main of a travelling creeper. It works very slowly, and continuously recovers the finest coal-dust as it settles down. An elevator *s* raises the collected fine coal to the hopper *q* (Fig. 2) where it either may be stored separately or mixed with the pearls. At the other end of the sludge-pit there is an overflow conveying the water into a clear water-tank. The centrifugal pump *t* delivers the water through a water-pipe system to the several machines.

The plant is worked by an engine with two cylinders each, 18 inches in diameter, and 4 feet stroke, running at 52 revolutions per minute, at 40 lbs. steam pressure. The power is taken from the engines to the main shaft by an 18 inches wide camel-hair belt; the engine-pulley is 7¾ feet in diameter, and that on the intermediate shaft 6 feet in diameter.

The washery has been in operation for four years, and during that time has caused the loss of two hours' output only, through the main belt breaking.

The Lührig plant does its work satisfactorily, and there have never been any complaints about dirt. The ash in the unwashed gum coal is about 22 per cent., and in the washed pearl dross 3·10 to 4 per cent.

The following are the results of a week's working of the washer, commencing on September 26th, and ending on October 1st, 1893:—

I.—*Capacity.*—The quantity of raw material put through the washer was 2,659 tons, the time worked by machine being 35 hours, an average of 7 hours per day; the average quantity of coal put through per day of 7 hours being 532 tons, or 760 tons per day of 10 hours.

II.—*Classification of Raw Material.*—The raw material was classified by the plant as follows:—

	Tons.	Per Cent.
Treble nuts	511 ...	19·21
Double "	544 ...	20·46
Single "	895 ...	33·66
Pearl dross	139 ...	5·23
Mixed pearl and sludge (used for boiler firing)	250 ...	9·40
Rubbish	320 ...	12·04
Total	2,659	100·00

III.—*Classification of Clean Coal.*—The clean coal may be distributed as follows:—

	Tons.	Per Cent.
Treble nuts	511 ...	21·85
Double "	544 ...	23·26
Single "	895 ...	38·26
Pearl dross	139 ...	5·94
Mixed pearl and sludge (used for firing at pits)	250 ...	10·69
Total	2,339	100·00

IV.—*Costs of Washing.*—The costs of washing are distributed as follows:—

		s.	d.	Amount. £	s.	d.	Total Cost.	Per Ton. d.
Wages—								
1 Engineman	5 days at	4	0 ...	1	0	0		
1 Man in washer	5 "	3	8 ...	0	18	4		
1 " "	5 "	3	6 ...	0	17	6		
1 " at rubbish	5 "	3	6 ...	0	17	6		
1 " "	5 "	2	6 ...	0	12	6		
1 Boy "	5 "	1	8 ...	0	8	4		
1 Pony "	7 "	1	6 ...	0	10	6		
							5 4 8	0·54
Repairs, stores, steam, etc.—								
1 Engineman	1 day at	4	0 ...	0	4	0		
1 Washerman	1 "	3	8 ...	0	3	8		
1 "	1 "	3	6 ...	0	3	6		
Proportion of mechanic's time and material			... ...	0	6	0		
Lubricating oil (1 gallon)			... ...	0	1	0		
Cylinder oil ($\frac{1}{4}$ gallon) ...			... ...	0	0	3		
Waste (6 lbs.)			... ...	0	1	2		
Estimated cost of steam...			... ...	1	10	0		
							2 9 7	0·25
Total cost of washing 2,339 tons ...							£7 14 3	0·79

Dross washing was practised at North Motherwell for some years before the establishment of the Lührig plant, so that a comparative table of values of products before and after the plant was set to work would not be of much service; but the following results of a trial washing made at Bardykes colliery in December, 1891, of dross sent from a neighbouring colliery are instructive.

The quantity of raw dross received was 55 tons, valued at 3s. per ton, £8 5s. 0d. The products got from washer and values were :—

	Per Cent.	Tons.	Cwts.		s.	d.	£	s.	d.	£	s.	d.
Treble nuts ...	10·62 ...	5	16	at	7	0	2	0	6			
Double „ ...	16·58 ...	9	1	„	6	0	2	14	3			
Single „ ...	43·40 ...	23	14	„	4	3	5	0	9			
Pearl dross ...	9·53 ...	5	4	„	3	0	0	15	6			
Smudge ...	10·62 ..	5	16	„	1	0	0	5	9			
Dirt ...	9·25 ...	5	1		—			nil.				
										10	16	9

This experiment shows a profit of £2 11s. 9d., or of 11¼d. per ton upon all the material treated. The values of the coal were supplied by the sales department as the current prices at the date of the trial.

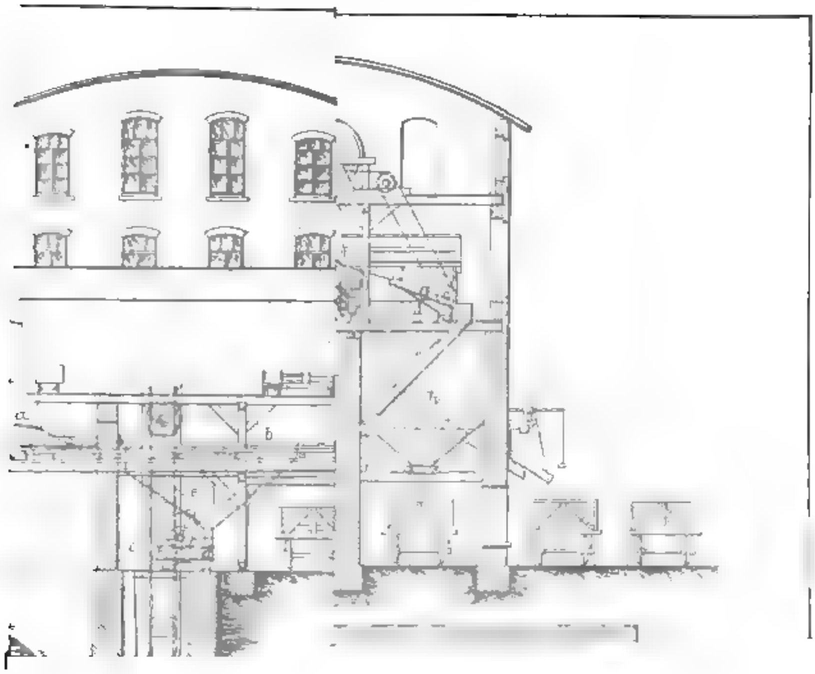
This sample of coal contained only 9·25 per cent. of rubbish ; and as North Motherwell colliery dross contains 12 per cent., it may be assumed that it was not worth any more per ton in the raw state.

The quantity of raw dross washed at North Motherwell colliery in 1892, was 125,704 tons ; and if a difference of 11¼d. per ton be allowed between washed and unwashed material, the sum of £5,892 7s. 6d. is obtained for the year by the use of the Lührig washing-plant.

The sample of dross under review, while cleaner than North Motherwell dross, has a lower proportion of the larger nuts ; and if the same rates be placed against the North Motherwell products, a higher average price per ton is obtained. Taking 100 tons, the products and values would be :—

	Tons.		s.	d.	£	s.	d.	£	s.	d.
Treble nuts	19·21	at	7	0	7	4	6			
Double „	20·46	„	6	0	6	2	9			
Single „	33·66	„	4	3	7	3	0			
Pearl dross	5·23	„	3	0	0	15	8			
Mixed pearl and sludge ...	9·40	„	1	0	0	9	4			
Rubbish	12·04		—			nil.				
								21	15	3

This table showing a profit of £6 15s. 3d., or a difference of 1s. 4d. per ton, which, multiplied as before by 125,704 tons, yields £8,380 5s. 4d. as the saving for the year in favour of using the Lührig washing-plant. The cost of washing must be deducted from this amount. This cost on clean coal is 0·79d. per ton, but on the raw material the cost is 0·70d. per ton, or in all £366 12s. 8d., which, taken from £8,380 5s. 4d., leaves £8,013 12s. 8d. as the net profit.



The PRESIDENT said they had already had a committee on the subject of coal-cleaning, but evidently the subject was not thrashed out.

Mr. DIXON asked, in the bringing out of the results, if the divisor included the dirt?

Mr. HOGG answered in the affirmative.

Mr. JOHN CUNINGHAME (Glasgow) said he could only refer them to the source from whence he got all his information on the subject of the washer, viz., Mr. Hogg, who was quite able to answer any questions that they might think proper to put to him.

Mr. HUGH JOHNSTONE (Glasgow) said he did not observe that Mr. Hogg made any allusion to the gross cost of the machine, and it did not appear that he included anything for redemption of capital and depreciation of plant.

Mr. CUNINGHAME said he did not think the paper included anything for interest and depreciation.

Mr. HOGG said, in thinking over the matter, he came to the conclusion that it was better to show a profit, if profit were to be shown, at one place, and, of course, it came out at the end. If he had put anything for interest and depreciation against the working cost it would have reduced the amount shown as profit obtained by the use of the machine.

The PRESIDENT asked if the Lührig washer was in use at any other colliery?

Mr. ARNOTT said the Lührig washer was also in use at Bardykes, Rosehall and Leven collieries.

Mr. CUNINGHAME thought it would be a mistake to give the cost of the machine at the Motherwell collieries. He did not think the knowledge of what had been spent in this case would add much to the knowledge which others, wishing to adopt it, desired.

Mr. FAULDS understood that the machines were now sold at a much cheaper rate. Accordingly, Mr. Hogg might be able to give the approximate cost.

Mr. CUNINGHAME said that although he was a director of the Lührig Co., he would prefer to leave it to their agent to supply this information.

The PRESIDENT asked what was the quantity of coal that could be economically treated by the machine?

Mr. CUNINGHAME said he thought, under favourable circumstances, it might be applied to from 150 tons a day and upwards of dross or doubles, trebles, and other washable material.

The discussion was then adjourned.

DISCUSSION UPON MR. V. C. DOUBLEDAY'S PAPER ON "THE SUSSMANN ELECTRIC LAMP."*

The SECRETARY asked if Mr. Doubleday could vindicate the statement that an incandescent lamp was absolutely incapable of igniting gas?

Mr. DOUBLEDAY replied that a large number of the incandescent glow-lamps had been broken over gas jets and in explosive mixtures, and in no case, with these small lamps, had they been able to produce an explosion.

The PRESIDENT asked if it was not possible that even with this very small lamp, between the breaking of the filament and its extinction, fire-damp might not be ignited?

Mr. DOUBLEDAY said that as a matter of fact, before this could occur, the filament would have broken.

Mr. JOHNSTONE asked of what nature was the filament?

Mr. DOUBLEDAY—Simply carbon. In reply to the President he said he considered the concussion alone sufficient to destroy the filament.

Mr. DIXON said the author of the paper might be wrong in claiming absolute security for this lamp. At the same time the same danger applied to every lamp if they broke the glass. He would advise him not to make an absolute claim to safety, but to say that it was a step in the right direction. If they admitted that they admitted quite enough.

Mr. DOUBLEDAY said they had a right to say that the lamp was absolutely safe. Even admitting for a moment, for sake of argument, that it was possible for it to ignite gas (which it, however, was not), it was even then better than other lamps.

Mr. JOHNSTONE asked if, in the event of the breaking of the globe and consequent destruction of the filament, there was no chance of sparking if the battery was switched on?

Mr. DOUBLEDAY said that would be impossible.

The PRESIDENT asked if the lamp contained a primary or secondary battery?

Mr. DOUBLEDAY said it was a storage-battery, requiring a dynamo to charge it, primary batteries being now out of court. He further explained that the lamp when charged would burn fifteen hours, and in order to know if it was charged, they had only to put it on to the volt-meter.

The PRESIDENT closed the discussion, and conveyed a vote of thanks to Mr. Doubleday for bringing the lamp before the members.

The meeting then closed.

* *Trans. Fed. Inst.*, vol. vi. page 264.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

SPECIAL GENERAL MEETING.

HELD IN THE STEPHENSON MEMORIAL HALL, CHESTERFIELD,
NOVEMBER 4TH, 1893.

MR. G. J. BINNS, COUNCILLOR, IN THE CHAIR.

The CHAIRMAN said the meeting that day was not an ordinary one but was specially for the discussion of papers that had been printed and issued in the *Transactions*, but from want of time at the Ordinary Meetings had not hitherto been adequately or at all discussed. The list, as they saw, was of considerable length, and hence he would not detain them by any preliminary remarks of his own. He should like, however, to refer to three members whose presence amongst them would be no longer felt, who had been recently removed by death—he alluded to the late Mr. Holdsworth, Mr. G. R. Turner, and Mr. Withers. It so happened that he (the Chairman) had been out of the country for many years, but Mr. Holdsworth was one of his earliest recollections, and his kind, genial nature had been very much appreciated by many of them. Mr. Holdsworth was one of the oldest coal-proprietors in that district, and his loss would be very much felt. With Mr. G. R. Turner and Mr. Withers his acquaintance was but slight.

The SECRETARY announced the election of the following gentlemen:—

MEMBERS—

Mr. JOSEPH WILMOT BARLOW, Colliery Manager, Hardwick Colliery, Heath, Chesterfield.

Mr. CHARLES M. HUMBLE, Colliery Manager, Warsop Main Colliery, Notts.

Mr. CHARLES LATHAM, Mining Engineer, Lecturer on Mining to the County Council of Notts., 7, Hope Drive, The Park, Nottingham.

Mr. HENRY LEESON, Colliery Manager, North Wingfield, Chesterfield.

DISCUSSION ON MR. J. P. HAMILTON'S PAPERS ON "THE WITWATERSRAND GOLD-FIELD, TRANSVAAL, SOUTH AFRICA,"* AND "NOTES ON THE NATAL COAL-FIELDS."†

The CHAIRMAN said he noticed in the first paper that some of the phenomena were the same as he had seen in other parts of the world, that was with regard to the free-milling ores which were found on the surface. Was the difference in colour due to oxidation or not? Then Mr. Hamilton did not tell them why the gold was only worth £3 10s. an ounce; possibly it was due to the presence of silver.

Mr. C. J. OLIVER (Chesterfield) said Mr. Hamilton stated that gold was supposed to have been held in solution; he would like to know how it had been dissolved?

The CHAIRMAN asked whether it was correct that the Natal coal was of Triassic age, that the measures were false-bedded, and that the coal was inconstant, both in thickness and lateral extent? He also asked whether 5s. 9d. per foot, the cost of diamond drilling, included 4·8d. per foot, the cost of replacing the diamonds, which was an extremely low cost? He (the speaker) had had diamond-boring done in England, but it had cost a great deal more than that, even by contract.

Mr. J. P. HAMILTON (Loscoe) replied that the average value of the gold per ounce varied from 70s. to 72s. 6d. It contained a small percentage of silver and a little copper. As the depth increased, the percentage of copper grew greater. Owing to zinc being chosen as the precipitant of the gold in the potassium cyanide solution, used in the re-treatment of tailings by the McArthur-Forrest process, the gold becomes incorporated with it, the product being a mixture of gold and zinc, and not fine gold. The diamond-drilling was through soft sandstone, and the Natal Government only employed one European at each drill. They were chiefly worked with natives in Natal. The wages of Kaffirs were very different in the Transvaal from what they were in Natal. In Natal the Kaffirs were paid 30s. per month, including food, but in the Transvaal they got £2 per week and food in addition. The price of 4·8d. per foot was included in the amount he had mentioned. He had bored at as low a cost as 2s. 3d. per foot, employing Zulus at the drills. Since his paper was written

* *Trans. Fed. Inst.*, vol. iii., page 857. † *Ibid.*, vol. iii., page 874.

the production of gold in the Transvaal had very much increased, and in August, 1893, amounted to 136,000 ounces, which exceeded the gold output even in Russia, so that the Witwatersrand was now the greatest gold-mining district in the world.* The gold might have been in solution, but he did not think that problem had been solved by anybody. However, he saw no reason why gold should not have been in solution and was still being formed in the reef, being precipitated by some chemical agent contained in the reef-matter. The variation in colour of the reef was probably due to oxidation.

The CHAIRMAN said they were much obliged to Mr. Hamilton for the valuable papers and for his presence there that day. Perhaps no one present, with the exception of himself and Mr. Hamilton, had had the pleasure of seeing the "colours" lying at the bottom of the pan after washing. In Australia, and he believed it was the same in South Africa, the method was to pick out the larger stones until they had left a small quantity of fine sediment in the pan. This they washed round gradually until they got the gold at the bottom; and then they washed off the sands until they only got such minerals as magnetic iron, scheelite, gold, platinum, and possibly cinnabar. Then they had to get rid of these with great care, and they saw the gold glitter at the bottom of the pan, sometimes in three or four colours to a dish, and these colours were so fine that it took from 6,000 to 7,000 to make a grain in weight. Thus it required the greatest care and skill, as there were some prospectors who were known to carry in their finger-nails sufficient gold to produce a colour.

Mr. T. A. SOUTHERN (Derby) seconded the vote of thanks. which was carried unanimously.

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* The Witwatersrand gold-mines gave the following results in August, 1893:—The 2,029 stamps at work crushed 201,391 tons of stone, milling on 27·50 days, and an average of 3·63 tons of stone crushed per stamp per day. The mills yielded gold weighing 94,778 ounces 18 dwts., and valued at £343,379, or 9·41 dwts. (worth £1 14s. 1d.) per ton. The concentrates yielded gold weighing 5,188 ounces, and worth £19,956. The tailings treated weighed 107,586 tons, and yielded gold weighing 29,913 ounces 9 dwts., and valued at £91,281, or 5·16 dwts. (worth 15s. 8d.) per ton. Alluvial diggings showed a yield of gold of 173 ounces 17 dwts., valued at £653. From other sources, 6,014 ounces 16 dwts. of gold were obtained, valued at £21,050. The total yield from all sources being 136,069 ounces, valued at £476,319.

DISCUSSION ON MR. W. S. GRESLEY'S PAPER ON THE "GEOLOGICAL HISTORY OF THE RAWDON AND THE BOOTHORPE FAULTS IN THE LEICESTERSHIRE COAL-FIELD."*

Mr. H. RICHARDSON HEWITT (Derby) said he did not rise for the purpose of refuting the evidence brought forward by Mr. Gresley, but rather to add a little to the information which that writer had kindly given. The greater part of the evidence is now obscure, and cannot be witnessed, and he considered that Mr. Gresley had been very kind in laying this information before the members. If Mr. Gresley had given a plan, as well as the valuable sections, it would have proved very useful as showing the position in which these faults lie in relation to each other. The main coal-seam east of the Rawdon fault has long since been met with, and has proved of very good quality and thickness throughout. The coal generally lies in a horizontal position, but rises sharply up to the Boothorpe fault beyond, when it is within a distance of 20 yards of it. The Boothorpe fault is not now visible in the railway-cutting at Woodville, as the embankment is entirely overgrown with grass, etc. The open clay-workings of the Boothorpe Pipe Company are situated on the western side of the fault and disclose a curious section of clays, sands, and marls, lying in a trough between the works and the turnpike road. The upper portion of these outcrop in the road, but are found again at the open workings of the Woodville Sanitary Pipe Company, showing that there did exist an anticlinal curve which had been denuded. The Boothorpe open hole does not disclose any slips or rolls, described by Mr. Gresley as being always present on the western side of the fault.

Mr. G. S. BRAGGE (Swadlincote) said he would like to mention one very interesting fact about the Boothorpe fault, which practically cut off the South Derbyshire coal-field, the throw of the fault varying from 1,000 to 2,000 feet, but the disturbances were not observable on the surface. In one case, the Granville Colliery Company were driving towards the fault, and the main coal-seam, which normally was 8 feet thick, thinned down to less than 3 feet. Evidences of the action of the fault on the eastern side were obscure. On the west, however, its presence was clearly marked, and within a distance of some 300 yards there was an anticlinal and a synclinal, showing that the measures were completely

* *Trans. Fed. Inst.*, vol. iv., page 431.

crumpled up by the large fault. He thought that the Boothorpe and Rawdon faults were connected with the faulting in the Charnwood district, and he thought that the Boothorpe fault was the same as the fault referred to in the paper which he wrote some years ago on the geology of the South Derbyshire and East Leicestershire coal-fields.*

Mr. A. H. STOKES proposed a vote of thanks to Mr. Gresley. He hoped that the present paper would not be the last that they would receive from him.

Mr. W. F. HOWARD (Secretary), in seconding the vote of thanks, remarked that apart from the value of Mr. Gresley's communication to persons interested in the Leicestershire coal-field, he considered it to be an admirable example for young geologists, particularly young mining men wherever resident, of the way in which to record and utilize their daily opportunities of observation. The paper had reminded him, more than anything he had read elsewhere, of a little treatise, entitled, *How to Observe in Geology*, by Mr. (afterwards Sir Henry) De La Beche, the first Director-General of the Geological Survey of the United Kingdom, a treatise that had long been out of print. He strongly advised the younger members of the Institution to study Mr. Gresley's paper, and to profit by the suggestive method it displayed in observations, inferences, and deductions; and he felt confident that the result would be beneficial both to themselves and to the Institution whose *Transactions*, as they should never forget, afforded an admirable means of submitting their ideas and discoveries to the test of friendly and encouraging criticism.

DISCUSSION ON MR. T. A. SOUTHERN'S PAPER ON "THE ESTIMATION OF THE ACTUAL EFFECTIVE PRESSURE OR WATER-GAUGE IN THE VENTILATION OF MINES."†

Mr. HENRY STOKER (Mansfield) said he would be glad if Mr. Southern would give what authority he had for the three propositions stated at the beginning of his paper. He (Mr. Stoker) could quote the authority of the late Mr. J. J. Atkinson (about 30 years ago) in which the third proposition in Mr. Southern's paper was contradicted in principle at that time, and the *Transactions* of the North of England Institute of Mining

* *Trans. Chest. Inst.*, vol. xv., page 198, and plates II. and III.

† *Trans. Fed. Inst.*, vol. iv., page 460.

and Mechanical Engineers (30 or 40 years ago) showed that these propositions were incorrect by the experiments in mine ventilation by steam-jets, water-fall, furnace, etc. In calculating the efficiency of any of the above means of ventilation they did not neglect to take into account the ventilating pressure due to the natural ventilation of the mine, and he could not believe that any mining engineer had fallen into the error of believing that the water-gauge recorded in the fan-drift represented the total pressure causing the ventilation of the mine. Hence he (Mr. Stoker) could not understand why Mr. Southern had attempted to disprove the three propositions, stated in his paper, when they had been disproved many years ago by the practice and writings of some of the chief mining engineers.

Mr. A. H. Stokes said he had been very pleased to read this paper, which, he thought, required great consideration. It opened up a question on which many of them had peculiar ideas, and probably they had modified their views with regard to the co-efficient of friction and water-gauges. Mr. Stoker had been speaking of what had been done 35 years ago. He should not like to refer to his (Mr. Stokes) own view and opinion 35 years ago. He had some peculiar notions then, but time and experience had changed many of the ideas taught him during his pupilage. He thought Mr. Atkinson and the other authorities mentioned, if they had been living now, would not have been of the same opinion as they were 35 years ago with regard to the co-efficient of friction, and he thought that Mr. Southern was to be commended for writing a paper and raising a discussion on the question.

Rev. G. M. Capell (Passenham) said that one point had struck him upon which he would like to make a remark. In his observations on the cases where the water-gauges at the pit-bottom were greater than the water-gauge in the drift leading to the fan, Mr. Southern ascribed it principally to natural ventilation, and with this he fully agreed. They had cases in that district where the same thing could be observed, for example, in the fan-drift at Oakwell colliery. The water-gauge was 2 inches in the drift, whilst on the doors below it was 2·4 inches, the drift was a large one (80 square feet area), and the water-gauge was placed in its centre ; there was 169,000 cubic feet of air per minute at 6·5 inches in the drift, but 7 inches of water-gauge was shown on the drift-door.

Mr. A. S. Douglas (Hucknall Torkard) said he would like to corroborate the statement that the water-gauge was sometimes higher on the separation-doors at the pit-bottom than in the fan-drift. At the Hucknall colliery the water-gauge was always ½ inch greater below ground than at the surface. There was a range of steam-pipes in the upcast shaft,

and the exhaust steam from two underground engines passed in to the upcast shaft. The natural ventilation varied from 25,000 to 30,000 cubic feet of air per minute after the fan had stood for 24 hours.

Mr. M. Deacon (Blackwell) said he believed that in a previous discussion Mr. Spencer had referred to the effect of falls in airways producing higher water-gauge as a fallacy. He thought that statement entirely depended upon the speed of the fan. If the same periphery-speed were maintained the same water-gauge would be registered, but if there were a very large fall impeding the air-current to an unusual extent he thought the effect would be that the fan would run away at a higher speed (unless the steam admission were automatically regulated), and therefore the difference in the water-gauge would be due to the increased periphery speed of the fan. He thought Mr. Southern was wrong in stating that mining engineers were not in the habit of considering the effect of natural ventilation in relation to the work done by fans. He thought most mining engineers considered that point in determining the power required to produce a certain amount of ventilation where a great difference of temperature existed in the upcast and downcast shafts. No doubt when the temperatures were not very different it was less necessary to take it into consideration.

Mr. A. H. Stokes said there was a time when mining engineers believed that if they had a fall in the mine the water-gauge would rise and give indication of such fall, and the idea was then accepted by many persons, but he did not think anyone had a similar belief now. No doubt if anything happened to raise the speed of the fan they would get a rise in the water-gauge, but if they got falls in the mine and kept the fan running at the same speed before and after the fall they would get the same water-gauge. The water-gauge was simply due to the speed of the fan. With regard to natural ventilation he thought one of the speakers gave a very apt illustration of its effect. Supposing they had a horse drawing a cart, the load was all on the horse, but if they put a donkey in front of the horse, were they not going to allow for the donkey? He supposed by natural ventilation the donkey was meant, but supposing that the horse walked the faster the donkey would be of no value at all, it would be simply in the way. He would also like to hear from Mr. Southern what he thought about the co-efficient of friction.

Mr. T. A. Southern said he had been asked to give his authority for stating that the three propositions at the commencement of his paper are widely accepted and relied upon by mining engineers. He had made this assertion entirely upon his own authority, based upon an extensive con-

nexion with mining engineers and mining students, and he still felt quite satisfied that his statement was neither unjust nor inaccurate, but, nevertheless, he was glad to find there were many who thoroughly concurred with his views. He was quite aware that the effect of natural ventilation, or a natural difference of temperature in air-columns, was demonstrated some thirty years ago in several papers by the late Mr. J. J. Atkinson and other writers, but, notwithstanding this, he had certainly found that it had, until quite recently, been very extensively ignored and overlooked in the practice of mining engineers, and in the education of mining students. Perhaps this was due to the fact that Mr. Atkinson's papers in the early *Transactions* of the North of England Institute were very abstruse, owing to the formulæ used. Mr. Capell had stated that the effect of natural ventilation was wholly included in a furnace water-gauge. That was not correct, because in any steep seam with a difference of temperature between air in the intake and return airways, the water-gauge of a furnace, calculated in the usual way from the mean temperatures in the upcast and downcast shafts, did not show the whole ventilating pressure. He quite agreed with what Mr. Deacon had said as to the effect of a fall; a very large fall in a main airway, which greatly reduced the total quantity of air passing through the whole mine, would cause an increase in the water-gauge, because the fan, with much less air passing, and the same steam supply, would run much faster. And, likewise, in furnace ventilation, the reduced quantity of air passing over the fire would be heated to a higher temperature, thus also causing an increase of the water-gauge; but the only airways where this could occur were those near the shafts, and in such airways the roof was always especially well supported, and very often by strong arching; hence, he would ask, was it fair to teach from this, as it had been taught, that the water-gauge could be used to ascertain when a fall had occurred in an airway? Splitting the air was now generally adopted, and most mines had a number of separate splits to ventilate them, often some 20 or 30 splits, and he would put it that even a fall which entirely stopped the ventilation of one of these splits could not possibly be detected by its effect upon the fan or furnace water-gauge. In regard to the best position for the water-gauge, Mr. Capell had told them that the direction in which the end of the tube points was immaterial, provided it is properly protected by a padding of wool. He would have expected that such padding, though doubtless very effective to obviate the oscillation caused by eddies in the air-current, would not counteract the direct impact, when the end of the tube is pointed against the air-current, or the induction when the end of the tube points in the

same direction as the air, and he felt unable to accept Mr. Capell's opinion on this point. In his own experience he had always thought that the correct position for the end of the water-gauge tube was at right angles with the air-current, or, better still, in a passage communicating at right angles with the airway, at a part of uniform section likely to be free from eddies; and he had always found that with the water-gauge tube in that position, he had obtained steady, regular, and apparently reliable readings. In reply to Mr. Stokes, he was not prepared to put forward reliable co-efficients of friction. Such co-efficients must vary a great deal according to the nature of the surfaces of the airways of each mine. This was shown, though further evidence of it was scarcely needed, by the results of Mr. Murgue's experiments. He had known, however, for several years past that the value of the co-efficient of friction ($k = 0{\cdot}00417$) used by the late Mr. J. J. Atkinson was some 6, 8, or 10 times greater than it should be, and he was astonished that this value had been quoted in nearly every text-book on the ventilation of mines published during the last twenty years, and without any warning or suggestion as to its inaccuracy. Moreover, it was very freely used in such text-books, in calculations which did not at all require the use of the co-efficient of friction; and the formulæ were rendered very much simpler and more easily explained when merely relative figures were used.

The CHAIRMAN agreed with Mr. Stokes that matters in mining had advanced during the past few years; he had pleasure in moving a vote of thanks to Mr. Southern for his paper, and for his attendance at the meeting that day.

Mr. M. DEACON, in seconding the vote of thanks, said that a knowledge of the defects pointed out by Mr. Southern would be of great service to the rising generation of mining engineers and colliery managers.

The resolution was then agreed to.

DISCUSSION ON MR. J. C. B. HENDY'S PAPER ON "EXPERIMENTS UPON A WADDLE FAN AND A CAPELL FAN WORKING ON THE SAME MINE AT EQUAL PERIPHERY SPEEDS, AT TEVERSAL COLLIERY." *

Mr. M. DEACON said he had recorded tests, which appeared in the *Transactions*,† and which did not entirely agree with those of Mr. Hendy, although they agreed very closely with some earlier experiments which Mr. Hendy had made and published in an earlier paper.

* *Trans. Fed. Inst.*, vol. iv., page 474. † *Ibid.*, vol. vi., page 188.

Rev. G. M. CAPELL said he was pleased to find that Mr. Deacon's tests of these two fans with drift-gauges and drift-measurements showed a result very near those of Mr. Piggford, and that the Waddle fan results agree very nearly with those contained in Mr Hendy's first paper on "The Stanton Iron Works Company's Collieries."* He did not think sufficient stress was laid on the disadvantage of position in the Capell fan, getting a large proportion of its total volume of air through an opening half the area of the drift, and the air being expanded into a large chamber before being again contracted to enter the fan-inlet. Then, again, there was in this arrangement the effect of a right-angled bend between the drift and the fan-inlet, which did not exist in the lead of the air to the Waddle fan. Recent experiments made by Mr. Deacon at the Shirland colliery proved that, in the case of air passing through a straight tube at a given water-gauge, if the volume was 100 cubic feet per minute, by putting on a right-angled bend, the other conditions being the same, the air-volume was reduced to 55 cubic feet per minute, but the water-gauge at the suction end of the tube remained the same in each case. He thought it was clear that, with the different conditions of lead to the inlets of the Waddle and Capell fans in the case under consideration (the Waddle fan having a straight lead, and the Capell fan being placed at right angles to the drift), it was impossible to say that the fans were working under similar conditions. The comparison was also unfair because the output of the Capell fan at Teversal colliery was only 70 per cent. of its body capacity, proving the existence of heavy frictional resistance. In the repetition of the experiments at Teversal colliery by Mr. Piggford, he wished merely to get at the drift conditions of the two fans, and to show the different conditions under which they were working, but he did not intend to dispute the results obtained by Mr. Hendy.

The CHAIRMAN proposed, and Mr. SOUTHERN seconded, a vote of thanks to Mr. Hendy for his paper, which was unanimously carried.

Mr. HUGH WADDLE (Llanelly) wrote that in the discussions which had taken place upon Mr. Hendy's paper comparing the old Waddle fan and the new Capell fan at Teversal colliery, a most important fact had been to a certain extent lost sight of. This fact was the dilapidated condition of the twenty-five year old Waddle fan when the experiments were made. Owing to corrosion, the blades were eaten away at the tips to such an extent that the effective diameter of the fan was practically reduced to about 28 feet. The inner ends of the blades were similarly eaten away, and both blades and casing of the fan were full of holes. Taking into

* *Trans. Fed. Inst.*, vol. ii., page 543.

consideration these serious defects, he (Mr. Waddle) was justified in stating that even if the experiments made under Mr. Capell's personal supervision were to be considered as being more correct than those made by Mr. Hendy the results merely showed that when the old Waddle fan was in good condition it was more efficient than the new Capell fan now is. He (Mr. Waddle) had only taken up this one point, which did not appear to have been mentioned previously.

DISCUSSION ON PROF. ARNOLD LUPTON'S PAPER ON "SPONTANEOUS COMBUSTION IN COAL-MINES."*

Mr. G. S. Bragge said most of the points had been dealt with in subsequent papers which had appeared in the *Transactions*. In his experience, he had found increased ventilation in collieries subject to spontaneous combustion did not tend to increase the number of gob-fires. At the same time he could not prove that increased ventilation had reduced the number of gob-fires.

Mr. A. H. Stokes said he now found a general opinion that increased ventilation did not increase gob-fires. He remembered many years ago they were always told, "Do not put in ventilation, or you will have gob-fires," but at the present time it was said, "Well ventilate the mine, keep it cool, and gob-fires will be prevented." One gentleman said that waxed walls should never be used, and that in his great experience their use was a mistake, whereas he (Mr. Stokes) found in Leicestershire that waxed wallings were largely and successfully used.

Mr. M. Deacon thought the question of props being left in the goaf had not been referred to by Mr. Lupton. From his experience in gob-fires, he believed their presence had a good deal to do with the propagation and encouragement of gob-fires. In scouring after gob-fires when they were only just indicated by moisture or by a white appearance on the packs, he had frequently found that the greatest heat existed in the neighbourhood of old props, and that the heat radiated from the prop as a centre, the prop itself frequently being charred. He also thought the nature of the roof was an important factor in the propagation of gob-fires. In a colliery he managed for some years, on one side of the pit the seam had a strong stone bind roof, and on the other side, it had a nesh or tender blue bind roof. There had never been a fire on the side where

* *Trans. Fed. Inst.*, vol. iv., page 481.

the strong roof existed; but they had constant fires, and they existed to this day, on the other side. He attached great importance to the fact that part of the blue bind roof was of the nature of an oil-shale, and he thought this was an important factor in the origin of the fires on that side of the pit. Pyrites had been frequently considered to be the cause of gob-fires, but in a seam, now being worked under his charge, the coal was so full of pyrites, that it had to be broken into small pieces in order to remove the pyrites, so as to prepare the coal for the market; now in this seam there were no fires and no signs of heating in the goaf. But the same pyrites, mixed with a certain proportion of coal, being deposited in a heap on the surface, took fire spontaneously after exposure for two or three years. He thought the fact of there being no fire in the pit was due to the excellent ventilation keeping the goaf perfectly cool, and to the hardness of the roof which could not enter into chemical combination with the coal and pyrites owing to the absence of disintegration.

Mr. Henry Stoker (Mansfield) believed that the subject of spontaneous ignition of carbonaceous material was very closely connected with their chemical and physical structure, with the quantity and quality of the occluded gases and liquids, with the fineness of the gob materials, etc. Experiments would be required to determine the pressure and rate of issue of the occluded gases and vapours, the molecular grouping of the chemical constituents in the coal while in a state of chemical equilibrium, and the chemical and physical effects produced by the disturbance of this stored-up physico-chemical energy during the issue of the gases. The chemical products formed by the oxidation of the gaseous hydrocarbons, the amount of heat developed by this oxidation, the rate of conduction and radiation of the above heat in gob heaps, etc., should also be carefully determined.

Mr. H. R. Hewitt (Derby) agreed with Mr. Deacon's remarks, and added that it was very noticeable that spontaneous ignition did not occur in mines where the roof was composed of sandstone, but it was nearly always present in mines where the roof was composed of oily shales. In the Leicestershire and South Derbyshire coal-fields ignition seldom took place until the roof had fallen to some extent: this circumstance appeared to show that the oxidation of the roof alone was, primarily, the cause of fire, and that the coal was quite of secondary importance. He should like Prof. Clowes to analyse a sample of the shale roof of the seam of a certain South Derbyshire colliery, and to communicate the result to the members. At one colliery near Derby, where spontaneous fires were

troublesome, the manager proposed to work the seam in small districts, and to cut off all ordinary gateways as quickly as possible by putting in new cross gate-roads, and then to take the roof down and bury the packs in all gate-roads which will acquire any great length. If a fire should break out in the packs and go through the new floor, it would then be an easy matter to put down a layer of flue-dust, sand, or burnt cinders, to prevent further damage being done.

Mr. A. H. STOKES said that, if the roof was the primary cause of spontaneous combustion, he could not understand how it occurred on board ship; and then again, as fire occurred in slack-heaps only a few feet thick on the surface, he was compelled to think that the fire was not always due to the the roof. It was known that combustion occurred in the cracks of the thick coal-seam. He thought that the chemical theory might be discussed with advantage.

The CHAIRMAN (Mr. J. G. Binns) acknowledged the truth of Mr. Stokes' remarks as to gob-fires. He had always paid considerable attention to the matter, and agreed with Mr. Stokes that the shale roof could not alone be blamed, for he had known gob-fires to occur frequently in collieries where the roof was composed solely of running sand, and in which, when a gob-fire occurred, it was only necessary to break the roof and let down the sand in order to check it. Mr. Hughes' paper* recorded gob-fires in a Staffordshire colliery where the roof was sandstone rock. Mr. Hughes was apparently answering a question of Mr. Bagnold Smith's, who held the same view as Mr. Hewitt; but Mr. Hughes' experience appeared to dispose of that idea. He had long been familiar with gob-fires in coal underlying coarse auriferous conglomerate, and shale was seldom found between it and the coal. Usually the coal and the conglomerate were coterminous, and there were certainly no shales that could cause fire. Mr. Lupton remarked that gob-fires were more frequent in thick than in thin coal-seams, but in a thick coal-seam there was more space left on extracting the seam. Mr. Lupton said that the only way to put out some fires was to submerge the whole pit with water, but he thought the last state of that pit would be worse than the first, for when the water was drawn off the fires would be found worse than ever. He had seen recorded the case of a colliery which was nineteen years under water, and where gob-fires occurred as soon as the water was drawn off. The question of solid coal had been raised, and he was told there was no such thing as solid coal. What he had meant was to make a distinction between unworked coal and goaf,

* *Trans. Fed. Inst.*, vol. v., page 392.

for they could not have coal which was absolutely solid and impervious to any medium. He intended to express—and he thought Mr. Hughes appreciated it—that fires did occur in pillars of coal fissured by pressure. As regards clay; Mr. Spruce condemned clay-walls, but though he (Mr. Binns) did not care for gob-roads, he believed a waxed-carving, if they had room to cut through and reduce its length if required, would be found to be very useful. He had recently carried wax-carving over a length of 345 feet with once cutting off, and never had the slightest trouble. Although, possibly, the distances might not seem very far to the members in Derbyshire; a block of coal measuring 660 feet by 460 feet was worked downhill, which was against the rules of old-fashioned miners, who said that they must work uphill so that the carbonic acid gas might run down. They had 18 feet wastes and 9 feet pack walls—with good ventilation, and frequently the pack-wall was taken out in the back of the gob and the coal out over it, and it was possible to pass along the back side of the goaf with perfect safety. It was necessary to cut off these wastes with clay-walls, which was done, and they never had the slightest trouble. Gob-fires were practically unknown now where they provided against them, the only anxiety they had was as to the old workings where crushes came on, and there they had trouble. They discovered the presence of fire by steam condensing on the roof and occasionally a little stink. Ventilation should be pressed up to a certain point, but if maintained too long fire was produced. The question was when to take the air off, and this was where the experience of the skilled mining engineer was of value. Mr. Spruce* appeared to think that they wanted to blow out actual gob-fires by directing the air onto them. They found the hard sandstone-rocks which occurred at Netherseal very useful for making pack walls, and the miners had an idea that they kept the place cool, but he had not yet come to that opinion. The stone used, known as Eureka rock, was a hard pure sandstone, entirely free from any combustible ingredients. He agreed with Mr. Stoker that they wanted some enquiries by the physicist and chemist and metallurgist, but to do that they would require the aid of the capitalist, and he was afraid the capitalist was the last person to assist in the matter, although he was the person most interested. As Mr. Lupton was not present the Chairman then adjourned the further discussion of the paper.

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* *Trans. Fed. Inst.*, vol. v., page 21.

DISCUSSION ON MR. H. R. HEWITT'S PAPER ON "A NEW METHOD OF LAYING COAL-DUST."*

Mr. A. S. DOUGLAS (Hucknall Torkard) asked if the damp air caused by the water-jets would have the effect of assisting in producing gob-fires? He had had a jet at work, and he found that it moderately laid the dust at a distance of only 30 or 40 feet; and he was afraid that the number of jets sufficient to lay the dust in a large mine would make their general adoption somewhat expensive. Considerable difficulty was found in many collieries in keeping up the roof under ordinary conditions, and he feared that the moistening of the air would increase the cost in that direction.

Mr. C. J. OLIVER (Chesterfield) said he had seen the waterspray in use at a colliery in South Wales, where it worked successfully. The dust was sufficiently damped, the continuous action of the spray damped the dust as it was deposited, and tended to prevent the formation of a crust of damp dust covering a quantity of dry dust beneath it on the floor of the roadway. Another advantage was the pleasant coolness of the air in the roads, resulting from the introduction of the sprays.

Mr. H. R. HEWITT said he could not give a definite answer to Mr. Douglas' question about the effect of moist air on gob-fires. Mr. Douglas said that the spray-maker only threw the water for a distance of 30 or 40 feet. He would like to know what pressure he used?

Mr. DOUGLAS could not accurately say, but the pressure was certainly much less than that referred to in Mr. Hewitt's paper.

Mr. HEWITT said if there had been sufficient pressure the spray would have been noticeable for a distance of 120 feet. The water from the jets only covered the top of the dust. He thought if they wanted it to do more they would have to go back to the old system of water-carts; but that would not be a step in the right direction. He did not think that the water ejected from the spray-maker was of sufficient volume to do any damage to an ordinary roof, because the amount of moisture carried was imperceptible in the atmosphere. There appeared to be several ways of damping the coal-dust of mines, and he advised the adoption of some one system in each of the dusty mines of this district, if it was only for sanitary reasons, independently of its supposed benefits in other directions. He observed that Mr. W. H. Routledge† did not agree with him

* *Trans. Fed. Inst.*, vol. iv., page 494. † *Ibid.*, page 498.

as to the utility of spray-making jets; but he meant to imply that saturation could be obtained at any velocity of air, and that the greater the velocity the longer would the air-current retain the moisture put into it. He had not been able to carry out the suggestion of Mr. Routledge with regard to additional experiments, as the apparatus described in his paper was of a temporary character, and he did not know of any mine where a number of these spray-making jets was in operation, so as to allow of further experiment being made upon the subject.

Mr. Hewitt moved a vote of thanks to the Chairman for his services that day.

Mr. Deacon seconded the motion, and remarked that he thought this was the first meeting they had had for the discussion of papers only, and it had been a most successful one.

The Chairman briefly thanked the members, and the meeting then terminated.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,

DECEMBER 9TH, 1893.

MR. A. L. STEAVENSON, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on November 25th and that day.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. FRANK J. AGABEG, General Manager, Apcar & Co.'s Collieries, Sitarampore, India.

Mr. JOHN ALEXANDER CHALMERS, Mining Engineer, P.O. Box 357, Johannesburg, Transvaal.

Mr. JOSEPH CHATER, Mining Engineer, Bengal Nagpur Coal Co., Limited, Evelyn Lodge, Asansol, Bengal, India.

Mr. FRANCISCO M. COGHLAN, Engineer, Catorce S.L.P., Mexico.

Mr. F. LAWRENCE CORK, General Manager, Bengal Nagpur Coal Co., Limited, Barakur, Bengal, India.

Mr. THOMAS CROUDACE, Colliery Manager, West House, Haltwhistle.

Mr. JOHN ETHERINGTON, Consulting and Mechanical Engineer, 39A, King William Street, London, E.C.

Mr. CHARLES FERGIE, Mining Engineer, Drummond Colliery, Westville, Nova Scotia.

Mr. JAMES FLETCHER, Colliery Manager, Wickham and Bullock Island Collieries, Carrington, New South Wales.

Mr. EDWARD GLEDHILL, Mining Engineer, Carolina Hacienda, Honda, Republic of Colombia, South America.

Mr. WILLIAM GRIFFITH, Manager, The De Beers Prospecting Syndicates, Waterloo House, Aberystwyth, South Wales, and Fort Salisbury, Mashonaland, South Africa.

Mr. JOHN ERNEST HARDMAN, Mining and Consulting Engineer, P.O. Box 520, Halifax, Nova Scotia.

Mr. ROBERT GEORGE HIGBY, Mining Engineer, Manager, Borrea Coal Co., Limited, Sitarampore, Bengal, India.

Mr. ROBERT G. LECKIE, Mining and Metallurgical Engineer, General Manager, Londonderry Iron Co., Limited, Londonderry, Nova Scotia.

Mr. ALFRED BENJAMIN LINDOP, Mining Engineer, Blackball, *via* Greymouth, New Zealand.

Mr. GEORGE HAMILTON LLOYD, Civil and Mining Engineer, Dolgerddon, Rhayader, Radnorshire.

Mr. CARR WALLER PRITCHETT, Jun., Mining Engineer, Apartado 84, Pachuca, Estado Hidalgo, Mexico.

Mr. C. ROBINSON, Mining Engineer, c/o Messrs. Wilmard, Spillhouse, & Co., Cape Town, South Africa.

Mr. ALFRED F. SEECOMBE, Mining Engineer, Albaston, Gunnislake, Cornwall.

Mr. CHARLES WILLIAM SIBOLD, Civil Engineer, Public Works Department, Bengal Civil Service, Mirzapore, N.W.P., India.

Mr. PEREGRINE OLIVER WILSON, Mining Engineer, 30, Finsbury Circus, London, E.C.

ASSOCIATE MEMBER—

Mr. HENRY DAVIES, Lecturer in Geology and Mining for the County of Glamorgan, Treharris, R.S.O., South Wales.

ASSOCIATE—

Mr. RALPH B. DORMAND, Under Manager, Waldridge Colliery, Chester-le-Street.

STUDENTS—

Mr. WARDLE ASQUITH SWALLOW, Mining Student, Bushblades House, Lintz Green.

Mr. THOMAS JAMES TOMLINSON, Mining Student, Harton Colliery, South Shields.

The following gentlemen were nominated for election :—

MEMBERS—

Mr. THOMAS ADAMSON, Assistant Manager, E.I.R. Collieries, Bengal, India.

Mr. WALTER BELL, Colliery Manager, 23 Windsor Terrace, Newcastle-upon-Tyne.

Mr. CHARLES BUTTERS, Engineer, Rand Central Ore-reduction Co., P.O. Box 1891, Johannesburg, Transvaal.

Mr. THOMAS CARR, Colliery Manager, Bengal Iron and Steel Co., Limited, Colliery Manager's Office, Burrakur, East Indian Railway, Bengal, India.

Mr. RICHARD E. CHISM, Mining Engineer, 3A, Independencia No. 1, City of Mexico.

Mr. NAPIER COCHRANE, Colliery Manager, Aldin Grange, Durham.

Mr. G. D. DELPRAT, Mining Engineer, c/o Messrs. Hill, Delprat, Ferdinand, & Carr, Campañas No. 15, Cordoba, Spain.

Mr. FRED W. HALL, Colliery Manager, Haswell Lodge, Sunderland.

Mr. GEORGE E. HARRIS, Mining Engineer, Margherita, Debrugarh, Upper Assam.

Mr. J. HOWARD JOHNSTON, Metallurgical Engineer, Establecimiento Minéral de Casapalca, Lima, Peru.

Mr. JOSEPH COOK NICHOLSON, Manufacturer of Engineers' Tools, 59, Side, Newcastle-upon-Tyne.

Mr. R. PRICE-WILLIAMS, Civil Engineer, Victoria Mansions, 32, Victoria Street, London, S.W.

Mr. JAMES PROUT, Mechanical Engineer, 16, Claremont Road, Redruth, Cornwall.

Mr. FRANCIS BELL FORSYTH RHODES, Superintendent, National Smelting and Refining Co., South Chicago, Illinois, U.S.A.

Mr. CHARLES ROBINSON, Mine Owner and Prospector, Steries Cottage, Marias Road, Cape Town, South Africa.

Mr. ALEXANDER SMART, Assistant Engineer, De Beers Mine, Kimberley, South Africa.

Mr. FRANK R. SYKES, Colliery Manager, Springwell Villa, Bishop Auckland.

Mr. JOSEPH WOODBURNE, Mining Engineer, Kimberley Mine, Kimberley, South Africa.

ASSOCIATE MEMBERS—

Mr. ARCHIBALD BLUE, Director, Bureau of Mines, Toronto, Canada.

Mr. JOHN GOETHE EAST, Ship Share Broker, 26, Side, Newcastle-upon-Tyne.

Mr. JAMES I'ANSON, Fairfield House, Darlington.

Mr. ARTHUR C. PAYNE, Royal College of Science, South Kensington, London, S.W.

ASSOCIATES—

Mr. MICHAEL HESLOP, Under Manager, Rough Lea Colliery, Willington.

Mr. THOMAS WALLETT, Deputy Overman, Heworth Colliery, Felling, R.S.O., Durham.

STUDENT—

Mr. FREDERIC LANCELOT BOOTH, Mining Student, Ashington Colliery, Morpeth.

DISCUSSION ON MR. D. MURGUE'S PAPER ON "THE FRICTION OF, OR RESISTANCE TO, AIR-CURRENTS IN MINES."*

The PRESIDENT said that Mr. Murgue's paper was very instructive, and recorded an example of carrying out very delicate experiments in a careful manner. For over thirty years he had accepted the statement of the late Inspector of Mines for the South Durham district—Mr. J. J. Atkinson, who had gone very carefully into the matter. That gentleman took the value of the coefficient of friction in the galleries of a coal-mine at 0·00417, and this had always been accepted as being at all events sufficiently accurate for practical purposes. Mr. Murgue, however, whom they all knew to be a very able authority on questions of mine ventilation, had made a series of experiments upon the length of airways not greatly exceeding (except in one instance) 300 feet. He had carried out the experiments by using a delicate form of water-gauge, whose readings could be observed, by means of a microscope, to 0·0008 inch, and he had by these means ascertained that the coefficient of friction for various kinds of passages varied from 0·00030 to 0·00241. This last value was just about one-half of the value recommended for use by Mr. Atkinson, but he (the President) was strongly under the impression that if they took all the galleries of a colliery between the downcast and the upcast shaft they would find that, although Mr. Atkinson erred on the safe side, the error was not of any great extent. And although Mr. Murgue gave excellent data, he (the President) would not recommend any one who had to erect a fan or who had to go seriously into the question of the friction of the mine to take any value very much less than that recommended by Mr. Atkinson. In conclusion, he would recommend the members to study Mr. Murgue's valuable paper, which he thought was of a most admirable and useful character.

Mr. T. L. ELWEN said that he had been very much interested in perusing Mr. Murgue's paper, with its record of elaborately conducted experiments. He had no wish to dispute the accuracy of the values of the coefficient of friction recorded in the paper as a guide in calculating the amount of pressure lost on current resistance in the varying types of airways. As, however, he (Mr. Elwen) had made this question the subject of a large number of experiments, some of which are recorded in the *Transactions*,† he might be excused for offering a few remarks, such as occurred to him while reading the paper. The statement, "that variations

* *Trans. Fed. Inst.*, vol. vi., page 135.

† *N. of Eng. Inst.*, vol. xxxviii., page 205.

of the volume of air did not at all modify the configuration of the curves of equal velocity"* was a surprise to him, and much more so was the difference between the maximum and minimum velocities of the air recorded in the tables. There was a very great difference between the maximum and minimum velocities, varying from 32 per cent. in experiment No. 10 to 435 per cent. in experiment No. 4. Mr. Murgue did not state what is the least distance from the sides at which the anemometers were held, and his impression was that timber or a jagged piece of rock was in the immediate vicinity, at any rate, in those examples which showed such a great difference. The result of special experiments which he had made by dividing into squares by strings two airways, (one square and the other circular), the nearest distance from the sides at which the velocity was taken being 1 foot, showed that for a low current-velocity in the square airway, the divisions in the lower half of the airway gave the highest velocities, in fact, in one instance the vanes of the anemometer would turn only near the bottom, the lowest reading not exceeding 40 per cent. below that at the centre. For a high current-velocity the readings at the sides more generally approached that of the centre. For a circular airway these percentage amounts were much smaller. In his experiments he had been unable to find that the rule adopted by Mr. Murgue was true, and would prefer to adhere to the system of squares for correct measurement of the volume of air. He was doubtful whether he could accept the coefficients of friction based on Mr. Murgue's system of deducing the current-velocity. Mr. Murgue did not state whether a fan or a furnace was the ventilating power employed, and in his (Mr. Elwen's) opinion the latter is very irregular and renders the deductions from comparative velocities valueless. A record of the revolutions of the fan—if such was used—during the period of such air-measurements was very desirable. He did not agree with Mr. Murgue's deductions on the same grounds as were expressed at the former discussion on this paper, namely, that the airways experimented on were too short to embrace a sufficient average working length of uniform area. The inevitable presence of refuge-holes, stenton-ends, etc., even in a regular sectional area, would modify the amount of resistance given by the author as for airways of regular section. He had already pointed out the effect of these interruptions to the regular course of an air-current in a paper read before the members, and he ventured to assert that had Mr. Murgue taken longer lengths of airway he would have found an increased amount of resistance over and above that which proportionately would have resulted from an

* *Trans. Fed. Inst.*, vol. vi., page 143.

increase in length. Mr. Deacon had referred* to a very high value of the coefficient of friction found in an experiment (made with the pit top-doors open) in which the air had a free course for a short length of the upcast shaft. He thought that this value was incorrect, and that it included the amount of power necessary to create the velocity, as well as the direct current resistance.

Mr. M. WALTON BROWN said the distance at which the anemometers were placed from the side of the airway in Mr. Murgue's experiments was shown in each of the diagrams, which were all drawn to scale. All of the experiments were made at the Bessèges and Créal Collieries, both of which were ventilated by means of centrifugal fans. The great difficulty in making any experiment upon the friction of air in mine galleries was that of obtaining a sufficient length of gallery possessing a sufficient regularity of area and of the nature of the sides.

The PRESIDENT said he did not think it should be difficult in this district to get a suitable place for experiments, and perhaps some of the members might be able to offer the use of suitable galleries for further experiments by Mr. Elwen.

The discussion was then closed.

Mr. J. P. KIRKUP read the following paper on the "Singareni Coal-field, Hyderabad, India":—

* *Trans. Fed. Inst.*, vol vi., page 175.

SINGARENI COAL-FIELD, HYDERABAD, INDIA.

By J. P. KIRKUP.

Discovery, Situation, and History.

The Singareni coal-field was discovered by Dr. King in the year 1872 while examining the geology of that part of the Deccan.

Subsequently, this field was partly proved by borings put down by officers of the Nizam's Government, and the results obtained were so satisfactory that a small trial-shaft was sunk, and a few hundred tons of coal taken from near the outcrop for trial in locomotive engines at Hyderabad. Nothing further was done until 1886, when steps were taken to continue the line of railway from Hyderabad to Bezwada, and to tap the field by a branch line.

The mining rights in the field and a monopoly to prospect the whole of the Nizam's dominions, an area of 81,000 square miles, for a period of four years, were granted to a syndicate, who formed the Hyderabad Deccan Company, with a nominal capital of £1,000,000, of which only £150,000 was subscribed, the balance of unsubscribed shares being held by the concessionaires.

Subsequently a Parliamentary enquiry was instituted to protect the native Government, and the concessionaires agreed to subscribe another £150,000 in deferred shares to ensure the confirmation of the concession. A considerable amount of capital has been expended on prospecting work at the so-called Golconda diamond mines (situated on the banks of the Kristna river), which have proved unsuccessful, and also in small areas of gold-bearing schists in the south-western part of the territory. Some old workings have been partially explored, but up to the present time no very rich quartz has been found.

The remainder of the territory has been practically unprospected by the company.

Active work commenced in 1887 under Mr. Hughes, superintendent of the Indian Geological Survey, with a staff of European miners. In the early stages much difficulty was experienced owing to the ground being covered with thick jungle; only one outcrop was visible, and the whole of the labour was imported. Owing to want of proper shelter, bad food supplies, and bad water, cholera and other diseases swept the place, causing at one time nearly the whole of the people to decamp.

Mr. Hughes was subsequently able to much improve matters by instituting order and cleanliness and improving the water-supply.

The coal-field is situated in about North latitude 17 degs. 30 mins. to 17 degs. 40 mins., and East longitude 80 degs. 18 mins. to 80 degs. 25 mins., and is connected with the standard gauge Indian lines by the Nizam's State Railway.* It is 653 miles from Bombay, the great port of the western side of India, and 146 miles from Masulipatam on the eastern coast. The latter can hardly be considered a port, as ocean steamers are unable to shelter and have to lie out some distance from the shore. Madras when connected by the east coast railway, at present under construction, will be about 360 miles distant, but by the present route it is 695 miles. The Indian Government have not yet decided to construct this part of the line, but are pushing on with the northern section towards Calcutta.

Bezwada is a rising town on the north bank of the river Kristna, in British territory. It is 96 miles distant from the coal-field, and forms the junction of the east coast railway with the Nizam's State Railway and the narrow-gauge system of the Southern Maratta Railway. A fine bridge has been constructed by the Government of India across the Kristna river, to effect the junction of these railways and continue the east coast line northward towards Calcutta. The Godaverry river will be bridged shortly.

Bezwada is also situated on the system of canals, constructed under the direction of the late Duke of Buckingham for irrigation and light traffic. They connect the Godaverry river with the small port of Coconda, and also with Bezwada and Masulipatam and, crossing the Kristna river at the former town, are continued to Madras. These canals irrigate an enormous area of country and serve the purpose of a very large goods traffic during the wet season, from June to February. During the intervening dry months there is no water in them, and opportunity is then taken to remove the annual accumulations of silt.

Hyderabad, the capital of H.H. the Nizam's dominions, and Secunderabad, the British military cantonment adjacent to it, are the only towns of any consequence upon the line of railway in the Nizam's dominions. The only coal-consuming industries situated there, are a cotton-mill and an ice-factory, with brick and lime-burning carried on to a small extent.

* The position of the Singareni Coal-field and its railway connexions is shown on plate IV. *bis*, vol. xxxvii., *Trans. N.E. Inst.*

Gulbarga is another town where a cotton-mill has been established. Several smaller towns on the line of railway are shaking off the sleep of ages and becoming busy centres of trade in grain, oil-seeds, wool, and cotton, but no manufacturing industries, save the three previously mentioned, have been attempted.

Lack of security and want of confidence by the natives in the native Government have much to do with this, together with an objection to European enterprise within the State.

Physical Features.

The district of Telingana, in which the coal-field is situated, was once considered the "garden of India," but the disorder following its conquest by the Mahomedans converted it into a wilderness, from which, however, it is now gradually emerging under the more enlightened rule of H.H. the present Nizam.

The country is overgrown by dense jungle, and the traveller sees with regret merely the evidences of former cultivation. Huge tanks, formed by the construction of dams across small streams, have been allowed to fall into ruin, and the fertile lands, once well watered, are hardly visible, owing to the jungle which covers them.

A scanty population of aborigines procure their subsistence from small clearings, upon which they grow various kinds of pulse, millet, and maize.

The surface of the coal-field is gently undulating and encircled by craggy hills of primitive rock, the surrounding country being a most picturesque combination of hill and valley. The general elevation of the coal-field is about 700 feet above sea-level, and the surrounding hills are from 500 to 600 feet higher. The drainage is effected by three rivers, one from the northern extremity, one in the centre, and the third drains the southern portion of the field. The district is generally dry, even in the rainy season. The climate, though hot and relaxing, is fairly healthy during the hot months and throughout the rainy season, but during the months of November, December, and January malarial fever becomes very prevalent among Europeans and natives alike. This is no doubt due to the immense jungles of the district.

The temperature during the months of March, April, and May often rises to 106 degs. Fahr. in the shade, and seldom falls below 90 degs.

The rainfall is about 30 inches per annum ; it usually commences in the second week of June and finishes in September.

The quality of the water is bad, being generally brackish, and during

the rainy season it causes a severe form of scorbutic ulcer upon the legs and feet of the people. A small scratch will open out and spread into an enormous ulcer.

The inhabitants are chiefly aboriginal tribes called Koyavas. They are a quiet, inoffensive people, noted for honesty, are splendid woodmen, and with light axes of their own manufacture fell the hardest timber with consummate ease.

At the commencement of mining operations they were extremely timid and could not be induced to come to even the surface-workings, but afterwards they came forward in considerable numbers, and many who have taken to mining are efficient coal-cutters.

Another tribe, of wandering propensities, inhabits the jungles ; they are the Benjaries or Indian gipsies. They are possessed of large herds of cattle, and were originally, before the days of railway traffic, the great carriers of the country, grain being even now carried hundreds of miles upon the backs of their cattle. They are an athletic, fine race, and noted thieves, but the march of modern civilization is compelling them to find settled employment. The more open parts of the district are peopled by various castes of Hindoos, the official classes being Mahomedans. The villages are chiefly peopled by cultivators and small traders. The cultivator class furnishes the greater part of the labour at the collieries.

Geology.

The Singareni coal-field (Fig. 1, Plate XII.) is a small outlier of the great deposit of Indian Coal-measures found in the Godaverry valley. It includes representative beds of all the formations of the Lower Gondwana system, and occupies an area of about 26 square miles.

Indian geologists have divided the formations there found into Upper and Lower Gondwana,* and these are further subdivided as follows :—

- Upper Gondwana—
  - Chikiala sandstones.
  - Kata sandstones.
  - Maliri sandstones.
- Lower Gondwana—
  - Kamthis sandstones.
  - Barakur beds.
  - Talchir beds.
- Vindyan—
  - Metamorphic schists.
  - Crystalline limestones.
- Gneiss.

Fig. 2, Plate XII., shows the structure of the coal-field and the relation of its three geological divisions.

* These measures are the equivalent of the Triassic formation.

Coal is found in the Barakur beds of the Lower Gondwana group, and in the Singareni field the three formations of that group are all very distinctly shown: in this respect it resembles the larger neighbouring area of the Godaverry valley.

It appears at parts of the boundary as though the Singareni field had been faulted into a trough of the earlier rocks, and thus preserved from influences which would otherwise have denuded it previous to the deposition of the Kamthis beds. Evidences of faulting are plainly visible on both the north-eastern and south-western boundaries of the coal-field, where the Gondwana group abuts against the crystalline Vindyan and Gneiss-rocks, although at the centre of the eastern boundary a natural contact is evident. The Barakur rocks are there found lying naturally upon the Gneiss, as proved by borings.

The Kamthis rocks have evidently suffered great denudation at a later period; with the exception of a solitary hill about 500 feet high on the north-eastern edge of the field, they are not of greater thickness than 100 feet, and in places nearly the whole has been denuded and the Barakur rocks exposed on the surface.

The Kamthis beds of the hill referred to overlap the Barakur formation and rest upon Gneiss.

The upper beds of the Kamthis group, as exhibited in the hill, very much resemble the Barakur rocks, being light grey sandstones, with light shaly beds intermixed; they are, however, of a more coarse and gritty character, the quartz-grains being bound together by decomposed felspar. The lower beds of the Kamthis group have, however, a more distinct character, and consist of very coarse yellow, brown, and red sandstones, with thin beds of very pure white clay or kaolin. These rocks exhibit great irregularity of bedding, having a very irregular dip, and often showing the planes of separate beds running into each other. The thickness and character of these beds vary infinitely, even in very short distances.

Boreholes within 200 feet of each other on the line of dip never showed the same section, as will be seen from the sections on the following page. B is 400 feet to the dip of A, and D is 200 feet to the dip of C, the surface being about level.

The vivid coloration of the rocks is evidently due to the presence of iron, as some of the lower beds are highly ferruginous, and were formerly made use of by the natives for the manufacture of iron. A pisolitic ore formed on the surface by the joint action of rain and sun was gathered for the purpose.

A.

	Ft.	Ins.
Red soil	6	0
Kamthis—		
Yellow sandstone ...	17	0
Red sandstone	9	0
Yellow sandstone ...	24	0
Yellow sandstone ...	9	0
Yellow sandstone ...	7	6
Dark variegated clay ...	2	6
Yellow sandstone ...	39	0
Barakur—		
Grey sandstone... ...	—	

B.

	Ft.	Ins.
Red soil	4	0
Kamthis—		
Decomposed sandstone	6	0
Yellow sandstone ...	12	0
Variegated clay... ...	2	0
Red sandstone	3	6
Yellow sandstone ...	57	6
Variegated clay... ...	6	0
Barakur—		
Grey sandstone... ...	—	

C.

	Ft.	Ins.
Dark soil	3	0
Kamthis—		
Morum	4	0
Yellow sandstone ...	28	6
Variegated clay	2	6
Red sandstone	2	0
Variegated clay... ...	4	0
Yellow sandstone ...	7	0
Yellow clay	2	6
Barakur—		
Grey sandstone... ...	—	

D.

	Ft.	Ins.
Dark soil	2	0
Kamthis—		
Morum	7	0
Variegated sandstone ...	5	0
Yellow sandstone ...	48	0
Variegated clay... ...	2	0
Variegated sandstone ...	2	0
Variegated clay... ...	4	0
Variegated sandstone ...	4	0
Barakur—		
Grey sandstone... ...	—	

The outcrops of the Kamthis rocks usually weather into round boulder-looking forms with a tendency to disintegrate from the parent bed.

At Singareni, no fossil remains have been found in the Kamthis beds, elsewhere *Calamites* occur, but they are rare, and although these beds are classed by the Geological Survey as Kamthis, they may be Barakur rocks.

The Barakur, or coal-bearing formation of the field, is almost entirely covered by the unconformable Kamthis rocks (Figs. 2 and 3, Plate XII.). A small area on the eastern side, about the centre of the field, shows that the Barakur formation crops out in the river, adjoining a boundary of gneiss; and a narrow outcrop of the same beds is seen on the western boundary immediately opposite, abutting against Vindyan rocks.

The only outcrop of coal upon the field was that found by Dr. King in a pothole in the rocky bed of the river at the point *c*, indicated upon Fig. 1, Plate XII., on the eastern side of the field.

The general dip of the measures is south-westerly, being from 6 to 8 inches per yard at the outcrop, but it is probable that it will become flatter towards the centre of the basin.

The measures consist of light grey sandstone and dark shaly beds alternating with beds of coal. The sandstones are finer-grained than and quite distinct from those of the Kamthis series found above, the Barakur sandstones bearing a strong resemblance to some of those of the English Coal-measures. The bedding and general character of the Barakur rocks are much more regular than the Kamthis group, and the outcrops are easily distinguished by their more regular bedding, sharp edges, and a tendency to wash into potholes under the scour of a river-current. No distinguishing fossils have been found, but a few impressions of *Calamites* are occasionally seen on the roof of the King seam.

Another circumstance noted is that the soil overlying the Barakur beds is frequently impregnated with lime, which separates out in the form of nodules of Kunker limestone.

The general thickness of the Barakur beds is from 500 feet to 600 feet, as proved by borings to various depths at different horizons on the outcrop. The outcrop-edges of the seams abutting against the overlying Kamthis rocks are of a muddy, soft, peaty nature, which rapidly passes into good coal under the cover of Barakur rocks. These appearances indicate that the outcrop-edges of the seams have been subjected to considerable weathering agencies previous to the deposition of the Kamthis group.

The following may be taken as a characteristic general section of the coal-field :—

Name of Formation.	Description of Strata.	Thickness.
		Feet.
Kamthis ...	Yellow, brown, and red sandstones and clays	80
Barakur ...	Grey sandstone and shales	160
	Thick coal-seam	30 to 40
	Grey sandstones, shales, and thin coaly beds	100
	Coal-seam	2 to 5
	Grey sandstone...	35
	Coal-seam	2 to 5
	Grey sandstone...	40
	King coal-seam...	3 to 7
	Grey sandstone...	100
	Coal-seam	1 to 2
	Grey sandstone...	110
Talchir ...	Muddy, dun, and buff sandstone	200

Notwithstanding the fact of the Barakur rocks being generally hidden by the overlying Kamthis beds, various borings have proved them to extend over an area of about 12 square miles, and of that area about 9 square miles are coal-bearing.

The Talchir beds which are well developed, and seen on the surface at the north-eastern end of the coal-field, consist of well-marked sandstones and shaly mudstones of a dirty brown or dun colour. They lie at low angle upon the Vindyan crystalline rocks, and dip south-west underneath the Kamthis and Barakur groups to which they are unconformable. No coal has been found in these rocks in Southern or Central India; indeed they may be termed the farewell rock of the Indian Coal-measures, and are known as such if met with in boring for coal. At their base is a bed of conglomerate formed of fragments of the earlier rocks. This conglomerate shows evidence of glacial action, as observed by Mr. Fedden on the banks of the Pem river, south-west of Chanda, in the Central Provinces. It has a very small development at Singareni, but is of importance as showing the similarity of these Talchir rocks to those of other parts of India. Large sharp-edged boulders of clay-slate, measuring 16 to 20 cubic feet, and embedded in muddy sandstone, indicate the transporting agency of ice.

The faults appear to run along the strike of the Barakur beds, judging from those already met with. The greatest dislocation is about 100 feet, but they do not extend for any great distance, and rapidly tail out from the point of greatest disturbance The circumstance which has preserved the field from denudation, has, without doubt, subjected it to the faulting influences of lateral pressure, and for that reason much faulting may be expected to have occurred over the whole area of the Coal-measures.

No igneous rocks have been observed breaking through the Gondwana deposits, but on the western edge of the field there is a local outburst of amygdaloidal trap. It forms a small hill on the line of the boundary-fault.

The seams of coal, in descending order are:—The thick coal-seam (Fig. 2, Plate XII.) which has been proved, at various points by borings, to vary from 30 to nearly 50 feet in thickness, and consists of alternating beds of coal and carbonaceous shale, but has not been thoroughly tested by actual working. A superficial trial-working was made near an outcrop and a quantity of fairly good coal selected from the part explored. This sample was tried under stationary boilers and found to steam well. It assays:—

Fixed carbon	52·5
Volatile matter	34·5
Ash	13·0

It is highly probable that in deeper workings it may be found to contain useful beds of coal, associated (as in most thick seams) with beds of shaly matter.

The second seam, which lies about 100 feet below the thick coal, is very variable in thickness, ranging from 2 to 5 feet. It is a shaly coal mixed with bands of carbonaceous shale; and after a considerable trial down from the outcrop it was abandoned as worthless. The best portions of this seam contain 20 per cent. of ash.

The third seam lies about 35 feet below the second, and is also of very variable thickness, ranging from 2 to 9 feet. It is a hard, strong coal, containing 30 per cent. of ash, and is therefore worthless for commercial purposes.

The fourth or King seam, so called from its discoverer Dr. King, is the seam of greatest commercial interest at the present time, and is being extensively worked from the outcrop. It is a hard, semi-bituminous, steam coal, varying from 3 to 7 feet in thickness, and generally uniform in quality. The specific gravity is 1·34, and it assays:—

Fixed carbon	58
Volatile matter	32
Ash	10

Two analyses by Mr. Tookey, F.C.S., are as follows:—

Carbon	66·45
Hydrogen	4·19
Oxygen and nitrogen ...	10·61
Sulphur	0·45
Water	7·60
Ash...	10·70
	100·00

Volatile matter		25·25
Coke—		
Carbon ...	... 56·50	
Ash ...	... 10·65	
		67·15
Water		7·60

It yields a gas of fair illuminating power, but not a good coke, as the coal retains its original form when burned in a retort.

It forms a useful steam coal, burns freely, leaving a buff-coloured powdery ash, and does not clinker on the firebars. Exhaustive trials have shown it capable of evaporating in locomotive boilers over 7 lbs. of water per 1 lb. of coal. It is slightly inferior to that from the Bengal coal-fields, but superior to the Warora coal, and compares favourably with some Australian coals, as shown by Mr. Price Williams in his comparative tests (Appendix A).

Extensive trials on the Madras railway by Mr. Phipps have shown it to be from 10 to 12 per cent. inferior to Bengal coal, but at the same time it is a valuable fuel for steam-producing purposes. The coal does not stand exposure to the weather, for any length of time, without crumbling and

deteriorating to a great extent. If screened and carefully stacked, it will, however, stand for a couple of months fairly well. When stacked in bulk it is very liable to spontaneous combustion, if laid thicker than 5 or 6 feet. This is not due to pyrites, of which it contains very little, but to its affinity for oxygen which sets up a rapid development of heat sufficient to ignite the mass. The only safeguard is to stack thin and so allow the heat to escape more readily. Stock heaps were generally tested with iron jumpers forced down through them, and the point of greatest heat-development was usually found about 2 feet below the surface.

The King seam, extending over 9 square miles, and assuming it to have an average thickness of 5 feet, should contain 47,520,000 tons of coal, which, after making the most liberal allowance for loss and unworkable coal, should afford ample supplies of fuel without drawing upon what may be found of value in the other seams.

Method of Working.

The whole coal-field (Fig. 1, Plate XII.) lends itself to easy and economical working; its seams are found at shallow depths, commencing at the outcrops with slight coverings of the Kamthis strata, and dipping at low angles to the centre of the basin, where the greatest depth probably does not exceed 800 feet. The measures contain very little water, and when won by proper sinkings will readily drain to the pits and give very little trouble or anxiety.

At present the King seam has been opened out by means of incline-drifts through the Kamthis rocks, driven at a gradient of 1 in 5 to the outcrop in the direction of the dip of the seam. A shaft for ventilating purposes is also sunk to the coal in each case. Fig. 3, Plate XII., shows the outcrop of the seams and the overlying Kamthis measures, with a drift going down through the latter, and illustrates the present system of opening out.

The incline is continued along the dip of the seam, and workings opened on either side on the bord-and-pillar system. The levels are driven right and left at an angle of 95 degs. from the course of the incline, giving them a slight fall out-bye to facilitate tramming from the faces to the incline hanging-on, where a double-way is laid into each tramway-level.

In the early days of the colliery, the demand for coal in large quantities necessitated rather extraordinary measures being taken to get it. All the workings were made 12 feet wide and the pillars 12 feet square, thus removing about 75 per cent. of the seam in the first working. Fortunately the roof is a model one, and the seam is very strong, or a collapse might have occurred. It was, however, evident that this could not be continued,

the pillars were increased as the depth became greater, and the levels reduced from 12 to 9 feet in width. Under 150 feet of cover the pillars are made 24 by 21 feet or 30 by 15 feet, thus removing about 54 per cent. of the coal in the first working, without in any degree causing symptoms of crushing. The remaining coal of the pillars will be easily got by the use of chock-timbers, after a number of skilled miners have been trained.

Broken working has not been attempted on a large scale, as the coolies are naturally timid, working as they are under new conditions; but a small area has been worked in the broken, and only 10 per cent. of the coal lost under a cover of 120 feet.

Fortunately, in driving these workings to the deep, no great quantity of water has been encountered: otherwise very slow progress would have been made. As it is, the dip faces are always more or less wet and necessitate the employment of a large number of water-bailers to carry the water out to the waterways above, which conduct it to collecting-sumps, whence it is pumped to the surface by means of duplex ram-pumps driven by compressed air.

There are six mines at present worked by means of incline-drifts, as above described, and one small shaft from which coals are being drawn.

Naked lights are in general use, and consist of small tin-lamps of tea-pot form, capable of holding about 6 ozs. of a mixtore of $\frac{2}{3}$ of castor oil, and $\frac{1}{3}$ of kerosene. They are provided by the company.

The rate of progress made in driving the headings is exceedingly slow, when judged from an English point of view, and renders very tedious the work of driving out a sufficient number of working-faces to ensure a fair output. About 35 to 40 feet of 12 feet wide drifting is all that can be expected from six men working double in 8 hours shifts for a month's work, or about 12 cwts. per man per shift. This is more than the average output per man, which is about 10 cwts. per day per hewer.

The hewer undercuts the seam to a depth of 3 feet, and nicks one side of his working to a similar depth; and after drilling the shot-holes with a jumper the shot-firer charges and fires them. The hewer afterwards throws back the coal and trims his place ready for another driving. The shots are put into thin cotton-bags, into which the fuze is tied. The consumption of powder amounts to a little over 3 ozs. per ton of coal wrought. English powder is used, as the local supply is not satisfactory.

The loading into tubs is done chiefly by women and boys, who carry it in baskets from those faces into which the tramways cannot be got. Each woman will load about 1 ton in the shift of 8 hours.

Any timbering that may be required is done by a rough carpenter, and one or two coolies assisting. They cut the timber into the required lengths upon the surface, and take it where required.

Platelaying is done by a special man with assistant coolies; he lays any new line required, and maintains all the roads.

Tubs are trammed from the loading-faces by gangs of trammers, who make up the engine-loads, hang on the ropes, and signal the engineman.

Each shift is in charge of a native deputy or *mukadam*, who is responsible for the proper carrying on of the work and the due attendance of the people in his shift.

The daily superintendence of each mine is carried out by a native or Eurasian underlooker of some education and standing among the people. He is in attendance for the greater part of the working hours during which coal is drawn, namely, from 6 a.m. to 10 p.m., or 16 hours in all. He has charge of the mine under his superior, and sees that the workings are kept in a safe and proper condition by frequent inspections, he also sees that all the working-faces are kept true to centre-lines.

Three European assistants daily supervise the underground workings, controlling and directing all labour under them, and giving the course of all levels by centre-lines. They daily consult with the manager and report the condition of their division.

Owing to the roof of the seam being of a strong sandstone, and the general care exercised in superintendence, accidents have been very rare, considering the inexperienced labour employed.

In 1890, there was an average of 1,845 people employed, and the accidents were as follows:—

Accidents	Underground.	Surface.	Total.
Fatal	2	1	3
Serious	6	7	13
Slight	16	5	21
	24	13	37

In 1891 there were 2,686 people employed, and the accidents were as under:—

Accidents.	Underground.	Surface.	Total.
Fatal	5	2	7
Serious	9	11	20
Slight	2	7	9
	16	20	36

Experience in Indian coal-mining has shown that, owing to the small production per man, it is very difficult to work up a large output with

any degree of rapidity. It is on that account usual in shallow workings to remove from 60 to 70 per cent. of the coal in first workings, leaving very small pillars, and thus more rapidly win out an increased number of working-faces. As the cover increases, the size of pillars has of necessity to be increased, and the rate of progress becomes slower. To procure an output of 500 tons per day, about 1,000 coal-cutters are required and not fewer than 200 working-places. Experience has also shown that, for rapidly developing large outputs of coal in India in shallow seams, the mines must be numerous. In deep mines, rapid development and large outputs from individual mines is almost impossible with such labour as is available, if the due safety of the mines be considered.

When the time comes to work the deeper coal in India, suitable coal-cutting machinery will no doubt have to be employed. Shaft pillars from 100 to 200 feet square would occupy from 8 to 10 months in forming, and the number of working-faces that could be started in pillar workings would depend upon the depth. Allowing for a depth of 300 feet, and shaft pillars 200 feet square, the pillars should not be of less size than 30 by 60 feet, and that would allow of about 32 working-faces being started outside the shaft pillars; these if kept at work by a full complement of 192 men, would barely yield 100 tons per day. An output of 300 tons a day from one pit would be good work in India, and for that no engine running at a high speed would be required, as the drawing probably would be distributed over the greater part of the 24 hours.

The inefficiency and lethargy of the Indian labourer render it impracticable to get large quantities in a few hours as in England. To the Eastern mind time is no object.

The tramway-gauge is 2 feet, and is laid underground with 18 lbs. steel rails and steel sleepers; on the surface the rails are of 22 lbs. section, and laid on Grigg sleepers. The coal-tubs are built of $\frac{1}{8}$ inch steel plates (fitted with steel axles and Hadfield steel wheels 12 inches in diameter), and are of the following dimensions:—Length, 4 feet 4 inches; breadth, 2 feet 8 inches; and depth, 2 feet 3 inches. The tubs each carry about 12 cwts. of coal. A small number of tubs are built 6 inches lower in height, to accommodate lower portions of the seam. The first consignment of tubs was procured from England, but they are all now built at the colliery.

The whole of the mines are connected with a central heapstead by surface tramways, by which the coal is transported for loading into railway trucks after being screened. The heapstead consists of an earthwork embankment, faced by a masonry retaining-wall 25 feet high.

There are two ordinary bar-screens, which separate the coal into two classes: the best or steam coal being that which passes over $\frac{5}{8}$ inch bars having $\frac{3}{4}$ inch spaces between them. The small coal which passes through is afterwards screened by hand into nuts, over a wire-net screen of $\frac{3}{8}$ inch square mesh, as the market demand requires. At present a very large proportion is thrown upon the slack heap, there being no great demand for this class of coal, although it is excellent for raising steam in stationary engines. The proportion of steam coal produced is about 72 per cent. of the output. The remainder consists of about 16 per cent. of nuts and 12 per cent of dust coal.

The coal is hauled from the mines to the heapsteads by small locomotive engines of the following dimensions:—Cylinder, 7 inches in diameter and stroke of 12 inches; driving-wheel, 2 feet in diameter; the boiler, fitted with 51 tubes 2 inches in diameter, works at a pressure of 140 lbs. per square inch. They are practically able to haul a load of 14 tons up a gradient of 1 in 45, and including delays in shunting and making up the sets will transport a load of 20 tons of coal 1 mile per hour, including running back with the empty tubs on an average gradient of about 1 in 80 falling with the load.

No. 1 *Incline.*—The hauling engine has two cylinders, each 16 inches in diameter and 2 feet stroke, geared $3\frac{1}{2}$ to 1. There are a pair of drums with clutch-gearing, each 4 feet $1\frac{1}{2}$ inches in diameter by 18 inches wide, the depth of flange being 1 foot $1\frac{1}{2}$ inches. Steam is supplied at a pressure of 60 lbs. per square inch from two Lancashire boilers situated close by. There are four boilers, each 30 feet long by 7 feet in diameter, but only two of them are worked at once. The boilers also drive the workshop engine, which has a cylinder 12 inches in diameter and 2 feet stroke, and the air-compressor engines, which work alternately.

The No. 1 air-compressor has two cylinders, each 18 inches in diameter and 32 inches stroke. The air-cylinders are of the same dimensions. The No. 2 air-compressor has one cylinder 14 inches in diameter and 2 feet stroke: the air-cylinder being of the same dimensions. The No. 3 air-compressor has two cylinders, each 9 inches in diameter and 18 inches stroke. These air-compressors were originally erected to drive two Stanley coal-cutting machines, and facilitate the winning out of working-faces by hastening the driving of the main galleries. The coal was found to be too hard for the machines to work effectively, and as they were constantly breaking, their use was abandoned. The air-compressors are now used to drive the underground pumps and a small underground hauling engine. The air is conveyed to the various pumps in wrought-iron

pipes with screwed socket-joints, which are found to stand the changes of temperature best. There are six small direct-acting pumps worked by this means as required, and the most distant is over a mile from the air-compressor. The use of compressed air is highly suitable in Indian mines where, owing to the general high temperature prevailing, steam is not generally admissible, and the exhaust air assists in cooling and ventilating the workings.

No. 2 Incline.—The hauling engine has two cylinders, each 8 inches in diameter and 10 inches stroke, geared 4½ to 1. There are two drums, each 2⅝ feet in diameter, 10¾ inches wide, and 10 inches deep, with clutch-gearing. Steam is supplied at a pressure of 80 lbs. per square inch by a Cochrane boiler, 5½ feet in diameter and 11 feet high.

No. 3 Incline.—The hauling engine has two cylinders, each 12 inches in diameter and 12 inches stroke, geared 4½ to 1. The drums are fitted with clutch-gearing, and are 4 feet in diameter, 12 inches wide, with 1 foot flanges. Steam is supplied at a pressure of 80 lbs. per square inch by a vertical Cochrane boiler, 5½ feet in diameter and 12 feet high.

No. 4 Incline.—The hauling engine has two cylinders, each 14 inches in diameter and 18 inches stroke, geared 4 to 1. The drums are fitted with clutch-gearing, and are 4½ feet in diameter, with flanges 1 foot deep.

No. 5 Incline.—The hauling engine has two cylinders, each 8 inches in diameter and 13 inches stroke, geared 5 to 1. The drums are 3 feet in diameter, 9 inches wide, with 9 inches flanges. Steam is supplied at a pressure of 80 lbs. per square inch from a vertical Cochrane boiler, 5½ feet in diameter and 11 feet high.

No. 6 Incline.—The hauling engine has two cylinders, each 14 inches in diameter and 2 feet stroke, geared 4 to 1. The drums are 5 feet in diameter, 1½ feet wide, with flanges 10½ inches deep, and fitted with clutch-gearing. Steam is supplied from a Cochrane boiler, 6½ feet in diameter and 14 feet high, which will work up to a pressure of 100 lbs. per square inch.

Shaft.—A small shaft which is 100 feet deep is fitted up with a light iron-headgear and a single cage, in rope guides, with a counterbalance-weight. The winding engine has two cylinders, each 7 inches in diameter and 10 inches stroke, geared 9½ to 1. The drum is 53 inches in diameter and 8 feet wide. An old ship winch is also fixed on the surface, and a rope taken down the shaft to haul coal from workings to the deep of the pit. The ropes in use are Lang and Elliot locked coil of different sizes. The latter make of rope has given great satisfaction, and is being generally adopted.

The pumps in general use are small quadruple duplex rams, and simple direct-acting force pumps, with from 6 to 12 inches steam cylinder and 3½ to 6 inches rams and plungers. Compressed air is the motive power underground, and wrought-iron pipes with screwed joints are in general use.

The workshops are built of iron framing covered with corrugated galvanized sheets. The objection to the use of this material in a hot country like India is that during the hot season the temperature inside often rises to 120 degs. Fahr., a heat too great for even natives to work in well. They are fitted up with every class of machine that may be required for colliery work, including screw-cutting and pattern lathes, shaping and slotting machines, drilling machines, punching and shearing machines, bolt and screw-cutters, plate-bender, emery wheels, grindstone, Root blower for Smith's forges, band-saw, circular saw-bench, 7 cwts. steam hammer, and all necessary workshop tools. With the foregoing equipment all classes of repairs and constructive work are executed with facility, and all small crucible castings of iron and brass are made at the colliery. The workshops, engines, and machinery are in charge of an English mechanic, assisted by an Eurasian foreman. Many of the native artizans have become excellent workmen, and, although not such vigorous workers, are capable of turning out quite as good work as our own artizans.

LABOUR.

The supply of labour from local sources is precarious. Mining being new and strange to the people, and land being plentiful and cheap with a sparse population, the local people can only be depended upon in the months during which they are not occupied in cultivation. They have to some extent got over their timidity, but the class attracted by mining are from the very lowest castes of the population, and are by no means desirable as workmen.

The Telingana cooly is a shiftless creature, a slave bred by centuries of oppression from his former rulers, the Hindoos and Mahomedans. The Telingee measures the comfort of existence by the quantity of food and liquor he can get. They are a most improvident race, living to be in debt and drinking as long as they possess any money. It was a difficult matter to get them together after the pay so long as the money lasted, and often from 40 to 50 per cent. were absent for three or four days at this time. The castes represented are the Koombis or cultivators, Goola or shepherds, Dhirs, shoemakers, and Pariahs, the last three being the lowest and most numerous of all. The inhabitants of the

jungle villages have not taken well to underground work, but come in for surface labour. They are excellent woodmen, and for cutting and dressing timber are difficult to excel.

In contrast to the people of Telingana are the men from Northern India and the Maratta country, who are industrious and frugal to a degree, and can always be relied upon as regular workmen. These men return to their country after saving a little money, and frequently make use of the post office to remit to their families at home who are settled on the land as cultivators. Very few men are accompanied by their wives and families, and the attachments formed are generally of a temporary and unprolific nature, so that the juvenile population is very small, and the time when a race of men will be bred to mining on the spot is very far off.

A few Mahomedans are employed, but they do not as a rule take to labouring work, and are chiefly employed in official capacities or as artizans and engine-drivers.

The early experience of the management impelled them to adopt strict sanitary measures for ensuring the health of the place, which is situated in the midst of a wide jungle. The malarial emanations cause numerous fevers in the cool season, and the local water-supply being both meagre and bad in quality, combined with the general filthy habits of the people, if left to themselves, necessitated strict attention to sanitary matters.

Several blocks of stone buildings with galvanized iron roofing were built for the occupation of the imported people. The quarters were made about 10 by 12 feet each, and are quite large enough for three or four natives to occupy.

Lines were set out in squares for those who erected their own huts, care being taken that each was separated from its neighbour so as to facilitate sweeping up of the refuse, and afford isolation in case of fire. A hospital was erected, and a medical and sanitary staff organized, consisting of the medical officer, hospital assistant, rangers, and sweepers.

The rangers are on daily duty to prevent the fouling of the lines and compel the use of latrines, while the sweepers clean up all the dirt and filth that daily gathers about native quarters. They also visit the underground workings daily, and remove all excrement deposited there. The people are moreover prevented from drinking any filthy river water, which they prefer, if it be only from a running stream.

It soon became evident that the local well water was inadequate for the supply of a large population, and some springs of water situated about 3 miles from the colliery were taken advantage of. They issue from some limestone-beds of the Vindyan formation, in the bed of a river,

and have never been known to run dry. After the rainy season the quantity issuing is about 100 gallons a minute, but towards the end of the dry season it has been measured as low as 20 gallons per minute. A line of cast-iron pipes, 6 inches in diameter, was laid, and a small steam pump and boiler erected at the springs. The water is pumped to the colliery, and distributed to the different mines.

At present, the underground feeders, though small, are sufficient for boiler purposes, but owing to mineral and sewerage impurities are unsuitable for human consumption.

The result of the careful sanitation and superintendence of the water-supply has been an almost total absence of infectious epidemics during the past three years. Only one slight outbreak of cholera occurred from an imported case, and that was quickly stamped out. Careful sanitation and care of the water-supply from contamination will give almost complete immunity from cholera, that dread scourge of Indian towns. It is a very common sight to see natives perform their ablutions in the same stream from which they take their drinking water, and yet they are most particular in having their water-vessels clean and untouched by lower caste people. They prefer to dip their vessels into the well or pool, and some difficulty was experienced in getting them to use pumps. They got over this by each person or caste pumping their own water.

The majority of the people build their own houses in a very simple manner. With a few poles and grass-thatching they form a covered space 9 or 10 feet long, and 6 or 7 feet broad, 6 feet high, and plaster the floor and sides, which are only 2 feet high, with mud and cow dung. These do not cost more than 3 or 4 rupees each, timber being provided by the company. Rooms about 12 feet square, built of stone in blocks with corrugated roofing, cost about 80 rupees each. This roofing is not suitable, as it becomes excessively hot during the hot season. A very cheap and efficient house can be built with mud walls and thatched roof. The mud once dried will stand a very long time and becomes almost as hard as stone. Houses for European officials require to be solidly built to ward off the heat of the sun, and cost about the same (if built well) as similar buildings in England. A very good house of three rooms, one, say 20 by 30 feet by 18 feet, and two 20 by 20 by 15 feet with verandah and servants' quarters, can be built for about 8,000 rupees or £500.

At Singareni the men are paid monthly, two or three days being usually allowed to prepare the pay bills after the last day of the month. Each man is paid separately, with the exception of the coal-cutters, who are paid in gangs of four or six, as they work together on the same work.

The workshop foreman has consolidated pay of 150 Halli Sicca rupees per month with no fixed hours; two or three of the superior native fitters are also under consolidated pay of from 60 to 90 Halli Sicca rupees per month. These men are quite as good as the average European fitter. The mechanical department of the colliery is under the superintendence of a good English mechanic who has gained his mining experience there. No home-trained colliery enginewright is on the staff. The mechanical and artizan classes employed upon the colliery are worthy of every commendation. The capability of improvement shown by them, and their present efficiency are remarkable. The writer has not seen better work turned out of any colliery workshop at home, and the condition in which they keep the engines and pumps is equally satisfactory.

The underground labour is all divided into 8 hours shifts, and is paid at slightly higher rates than for surface-work. Coal-cutters are paid by the yard. The standard price being 5 Halli Sicca rupees per yard for a heading 12 feet wide and 5 to 7 feet high, places that are narrower or lower are paid at proportional rates. The earnings per man vary considerably, 10 rupees per month being about a minimum, and 20 rupees about the maximum earnings, all depending upon the efficiency of the workmen. Broken workings are paid at about two-thirds the price of whole workings.

Payments are witnessed by the underlookers and European officials, and are made in the local currency of the State of Hyderabad known as Halli Sicca rupees; the smaller coinage consists of dubs or pice, which are irregular pieces of bronze stamped with Persian characters. A more barbarous currency than the dubs could not well be imagined. The Halli Sicca rupee is of inferior value to that of the British Government, the nominal ratio being as 120 to 100, but the market value varies considerably, the average exchange rate being about 116. The Halli Sicca rupee is nominally equal to 96 dubs, six of which equal 1 anna, and one is equal to 2 pies. The market value of these varies from 94 to 104 per rupee, according to their scarcity or abundance in the bazaar.

The rates of wages paid to different classes of labour are as follows:— Surface coolies, who work from 6 a.m to 6 p.m., with two hours' interval, are paid 5 annas per day; women get 3 annas per day; heapstead men, 7 annas for 8 hours; fitters, 8 annas to 3 rupees for 10 hours; smiths, 8 annas to 1 rupee 8 annas for 10 hours; smiths' apprentices, 4 to 8 annas for 10 hours; carpenters, 10 to 14 annas for 10 hours; enginemen, 8 to 12 annas for 8 hours; firemen, 6 to 7 annas for 8 hours; and locomotive drivers, 12 annas for 8 hours. Fillers are paid 6 annas per day, when not paid by contract; women fillers get 3½ annas per day;

children, 2 annas; trammers are paid 7 annas, and general coolies 5 to 6 annas; deputies or mukadams are paid 16 rupees per month; under-lookers, 30 rupees per month; head platelayers, 12 annas per shift; carpenters, 12 annas; banksmen, at mouth of inclines, 6 annas; time-keepers, 20 to 25 rupees per month. Native clerks are paid 30 Government rupees per month, and a native chief accountant and cashier, 120 Government rupees per month.

THE NUMBER OF NATIVE WORKMEN EMPLOYED IN JULY 1892, WERE AS FOLLOWS:—

	Men.	Women.	Children.	Total.
Surface —				
Mechanics	19	—	—	19
Engine and pump men and firemen	91	—	3	94
Apprentices	5	—	—	5
Carpenters	13	—	—	13
Smiths and pick-sharpers	22	—	12	34
Labourers	13	2	—	15
Trammers	57	—	—	57
Screeners	12	—	—	12
Shunters	35	—	2	37
Stacking slack	24	60	13	97
Tramway men	30	—	—	30
	321	62	30	413
Underground—				
Coal-cutters	1,346	—	—	1,346
Fillers	141	357	56	554
Trammers	66	—	—	66
Platelayers	25	—	3	28
Watermen	94	—	3	97
Stonemen and shifters ...	138	38	3	179
Timberers	21	—	—	21
Deputies	38	4	—	42
Ventilating	7	—	7	14
Boys (greasers)	—	—	8	8
Miscellaneous	93	5	1	99
Petty contractors' (coolies)	74	43	1	118
	2,043	447	82	2,572
Totals	2,364	509	112	2,985

MARKETS.

The chief consumers of the coal at present are as follows:—

Railway.	Quantity per Annum. Tons.		Price per Ton at Colliery. Rupees.
Great Indian Peninsula	50,000	...	6
Nizam's Guaranteed State ...	16,000	...	6
Madras (sold through a contractor).	18,500	...	5
Southern Maratta	15,000	...	6¼

There are also a few mills and small works in Hyderabad and neighbourhood which consume nut coal.

The great distance from large centres of consumption and the consequent high cost of carriage militate against a large sale being made. The railway's minimum charge at present is $4\frac{1}{2}$ pies per ton per mile, which amounts to 2·34 rupees per 100 miles, and even at this comparatively low freight the coal cannot be put on distant markets to compete with English and other imported fuels. The opening of the new east coast railway to Madras will no doubt enable it to be got into that district at a lower rate, but even with the cheap water-carriage available from Bezwada, that has been found difficult owing to the low rate at which Bengal coal can be brought in by sea.

The delivery of Singareni coal in better condition by direct railway carriage will no doubt assist its introduction, and when some further extensions of the Southern Maratta railway system are completed the approach to the Kolar gold-fields will be shortened and it may be got there at a fair price.

There is very small hope of ever opening out an export trade from the coast, as the coal would require to be loaded into lighters and taken from six to eight miles out to sea to be got on shipboard. Widely extended sales will depend upon low freights and reduced selling price at the colliery.

With the exception of the Madras railway, those above mentioned are supplied direct by the mining company; all other consumers purchase through a native merchant, who has contracted to take 42,000 tons of steam coal and 21,000 tons of nuts at 5 and $2\frac{1}{2}$ rupees per ton respectively during 1892, and 66,000 tons of steam coal and 33,000 tons of nut coal during 1893 at the same figures. He is experiencing great difficulty in disposing of even the smaller quantities to be taken in 1892, and no market is at present evident for the larger quantities to be taken in 1893.

The capital expenditure upon the colliery, up to the end of 1891, amounted to 1,308,453 rupees, divided over the following general heads of expenditure:—

	Rupees.	As.	Ps.		£	s.	d.
Preliminary expenses	28,441	5	8	=	1,955	6	10
Construction of mines	158,750	6	1		10,914	1	9
Machinery tools and plant ...	691,947	9	6		47,571	7	11
Permanent way	113,202	5	4		7,782	13	3
Buildings	175,555	8	3		12,069	8	9
Water supply	8,751	10	0		601	13	5
Establishment	74,092	12	3		5,093	17	7
Medical and sanitation	13,705	6	2		942	4	11
Survey...	15,920	10	1		1,094	10	10
General contingencies	28,085	10	5		1,930	17	9
	1,308,453	3	9		89,936	3	0

For the amount of work done, the sum expended on preliminary expenses and construction of mines and buildings is exceptionally high, chiefly due to a forced development under unqualified and amateur supervision in the early days of the colliery. A large sum of money was also expended upon needless machinery, such as a Schiele fan and engine, iron head-gear, and winding-engine, all very good plant but bought before they were wanted. The cost of opening the early mines was about double what it ought to have been, and the buildings cost extravagant prices for badly finished work.

The progress of the output is shown by the following figures:—

	Tons.
1887	3,258
1888	13,382
1889	59,646
1890	125,470
1891	144,688
1892 (half-year)	75,875*

Previous to 1890 the cost accounts were not kept with any degree of care, but in that year the output cost, exclusive of royalty, 2 rs. 9 as. 4·88 ps. per ton; in 1891 it cost 2 rs. 4 as. 11·72 ps. per ton; and for the half-year ending June, 1892, it was 2 rs. 6 as. 3·15 ps., showing a reduction on the cost of 1890 as per detailed statement below:—

1890.	Rs.	As.	Ps.
Underground labour	1	6	10·55
Aboveground labour	0	6	7·03
Materials	0	7	4·67
Charges	0	4	6·63
	2	9	4·88
Rent	0	7	5·09
Total cost per ton	3	0	9·97
1891.	**Rs.**	**As.**	**Ps.**
Underground labour	1	4	11·93
Aboveground labour	0	5	9·40
Materials	0	5	9·45
Charges	0	4	4·94
	2	4	11·72
Rent	0	7	3·49
Total cost per ton	2	12	3·21
1892—Half-year ending June 30th.	**Rs.**	**As.**	**Ps.**
Underground labour	1	5	1·83
Aboveground labour	0	6	11·29
Materials	0	6	1·24
Charges	0	4	0·79
	2	6	3·15
Rent	0	7	0·39
Total cost per ton	2	13	3·54

* The last three years show the most rapid development of output in the history of Indian coal-mining.

The charge for rent has been fixed on the basis of 22 per cent of the nett profits, taking a fixed working cost of 2 rupees 6 annas in Government currency.

These figures in the early days of the colliery promise well for future cheap production, after labour becomes settled and trained to mining.

At present the slack and a large quantity of nut coal are unsalable. In 1890, this amounted to 24,312 tons, which was stacked, and destroyed by spontaneous combustion. The sales in that year amounted to 101,158 tons, which realized the average rate of 5 rs. 9 as. 8·7 ps. per ton, and the cost per ton sold, allowing for royalty, was 3 rs. 12 as. 6·8 ps., leaving a balance of profit of 1 r. 13 as. 1·9 ps. per ton.

In 1891, 27,335 tons of unsalable nuts and slack were produced. The sales amounted to 117,353 tons, which realized an average price of 5 rs. 7 as. 8·8 ps. The cost per ton sold, including royalty, amounted to 3 rs. 6 as. 7 ps. per ton, leaving a balance of profit of 2 rs. 1 a. 1·8 p. per ton.

In 1892, the contracted sales amount to 149,000 tons, which, allowing for unsalable slack, will require an output of 176,000 tons. The average selling price is 5 rs. 2 as. 7·87 ps., with an estimated profit of 1 r. 14 as. 7·8 ps.

The prospective sales for 1893 amount to 185,000 tons, which will require an output of 210,000 tons, leaving a balance of unsalable slack amounting to 35,000 tons to be thrown aside. The average selling price will be 4 rs. 15 as. 6 ps., and the estimated profit, 1 r. 14 as. 7·8 ps.

The commercial progress of the colliery is shown by the following statement :—

Year.	Sales. Tons.	Profit. Nett. Rs.	Profit. Per Ton. Rs.	As.	Ps.
1890...	101,158	184,384	1	13	1·9
1891...	117,353	243,147	2	1	1·8
Half-year ending June 30th, 1892	57,406	96,511	1	10	10·8

The present mines will not satisfy the requirements for 1893, and it is doubtful, even if they should, whether the contractor will be able to dispose of the largely increased quantity. It must be said that the foregoing statement of profits is a handsome return upon the capital expended, and shows the profitable nature of Indian coal-mining under favourable circumstances. Unfortunately the nominal capital of the company stands at £1,150,000, with a loss already of six years' interest to the shareholders, which will require enormous sales and a very high profit to be made, as the other departments of the company's business are in anything but a flourishing condition.

APPENDIX A.—RESULTS OF TESTS OF SINGARENI COAL BY A CALORIMETER, AND ALSO ON ONE OF THE NIZAM'S GOVERNMENT STATE RAILWAY LOCOMOTIVES, NO. 45 (A CLASS), IN COMPARISON WITH SIMILAR TESTS MADE OF COAL FROM VARIOUS COLLIERIES IN NEW SOUTH WALES, ON ONE OF THE GOVERNMENT LOCOMOTIVES (NO. 104) OF THAT COLONY, BY MR. R. PRICE-WILLIAMS.

Description of Tests.	Date of Trial	Coal: Specific Gravity.	Coal: Total Amount Burnt.	Coal: Lbs. Burnt per Sq. Ft. of Grate per Hour.	Coal: Burnt per Mile.	Water at 212° Fahr. converted into steam by 1 lb. of coal by Calorimeter.	Water: Total Amount Evaporated.	Water: Evaporated per Lb. of Coal.	Percentage of Locomotive Evaporative Power to that given by Calorimeter.	Ash.	Load on Journey	Time: Running	Time: Shunting or Standing.	Time: Total Time on Journey	Average Speed while Running.	Average Boiler Pressure.
			T. C. Q. L.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	%.	%.	T. C.	H. M.	H. M.	H. M.	Miles per Hour.	Lbs. per Sq. In.
SINGARENI COAL.																
No. 1, goods train—Secunderabad to Gangarwaram	Mar. 23, 1892	1·30	1 8 3 19	29·87	74·03	12·42	22,712	*7·01	56·44	10·60	673 11	3 29	1 2	4 31	14·38	135
No. 2, goods train—Secunderabad to Gangarwaram	Mar. 25, 1892	1·30	1 10 0 2	24·01	76·84	12·42	23,529	*6·99	56·28	10·60	667 16	3 29	2 21	5 50	13·92	135
No. 3, goods train—Wangapalli to Secunderabad	Mar. 29, 1892	1·30	1 4 2 3	31·35	75·77	12·42	20,579	*7·49	60·30	10·60	531 12	2 53	0 46	3 39	12·94	137
No. 4, mail train—Secunderabad to Gangarwaram, *via* Hyderabad	April 3, 1892	1·30	0 15 0 1	24·85	33·12	12·42	13,027	*7·75	62·39	10·60	229 9	2 18	0 31	2 49	22·06	135
NEW SOUTH WALES COAL.																
Great Northern Colliery Company ...	Mar. 20, 1890	1·34	2 19 0 0	33·7	47·2	12·03	44,965	*6·80	56·5	13·60	145 0	7 53	6 0	13 53	17·50	130
Metropolitan Coal Company	Mar. 22, 1890	1·38	2 12 1 14	33·9	41·9	12·29	44,285	*7·55	61·4	13·30	148 10	6 27	5 53	12 20	21·70	135
Northumberland Coal Company, Fassifern	Mar. 31, 1890	1·42	3 3 2 3	32·6	50·9	11·40	45,092½	*6·38	53·5	19·60	151 2	8 13	7 22	15 35	17·00	125
Waratah Colliery Company	April 2, 1890	1·30	2 13 2 15	32·4	42·9	13·92	44,455	*7·40	53·1	10·26	146 7	7 58	5 16	13 14	17·50	135

* The evaporative power on locomotives, according to Molesworth (p. 459), varies from 5·2 to 8 lbs.; Webb's compound locomotive has evaporated as much as 9·49 lbs. of coal.—Mr Worthington on "Compound Locomotives," vol. xcvi., *Proceedings of the Institution of Civil Engineers*, 1889.

NOTE.—The small amount of water lost through the injector overflow has not been allowed for, owing to the difficulty of estimating it. It does not, however, amount to more than 1 per cent., and would not appreciably affect the accuracy of the results here given.

APPENDIX B.—LOCAL PRODUCTS.

The following table gives the best local timbers available, although there is a large variety of other timbers, which in other parts of the dominions afford good supplies in the Singareni jungles they do not attain a serviceable size :—

	Local Name.	Breaking Strength. Lbs.	Weight per Cubic Foot. Lbs.
Tectona Grandis	Teak	600	38
Soymida Febrifuga	Somi	626	73
Chloroxylon Swietenia	Satinwood	800	57
Odina Wodier	Gumpani	300	50
Pterocarpus Marsapium	Bijasal	800	54
Hardwickia Binata	Eppa	940	82
Acacia Arabica	Babul	880	55
Terminalia Tomentosa	Nulla Muddi	677	62
Anogeisus Latifolia	Tiramani	870	60
Lagerstroemea Parvifolia	Chinangi	467	50
Adina Cordifolia	Bandari	464	40
Diaspyros Chloroxylon	Ilindu	—	—
Briedelia Retusa	Dudimuddi	525	50
Grewia Tiliæfolia	Daman	565	48
Milinsa Velutina	Baradudi	836	50

The breaking strains are for sections of 1 inch square, 1 foot between supports, and loaded in the centre.

The prices charged by H.H. the Nizam's Forest Department are as follows :—

Teak logs—

Dimensions. Cubic Feet.	Price per Cubic Foot. Halli Sicca Rs.	As.
3 to 8	1	0
8 to 10	1	2
10 to 12	1	4
12 to 20	1	6

Satinwood at same rates. Other timbers :—

Dimensions. Cubic Feet.	Cost per Cubic Foot. Annas.
3 to 8	8
8 to 10	9
10 to 12	10
12 to 20	11

Small rafters—

Girth. Inches.	Length. Feet.	Cost per 100 Feet. Halli Sicca Rupees.
18	12 to 15	25
15	12 to 15	12½
12	12 to 15	6¼

Prop-timber up to 24 inches girth is charged ½ anna per foot of length; a 6 feet prop thus costs 3 annas, plus the cost of cutting and leading.

Owing to the comparatively light rainfall the trees seldom attain any great size. The Eppa attains full growth and is a noble tree in the Singareni jungles. The others seldom exceed a size of 30 cubic feet in the log.

The local teak wood is very small and only useful for sleepers or small work. It is beautifully grained, and when polished becomes very ornamental.

Somi wood is a very fine timber resembling mahogany, and is chiefly used for ornamental work.

Satinwood is found of fair size, and is chiefly used for ornamental work and for bushing cart wheels.

Gumpani wood is one of the few Indian timbers readily sawn by the circular saw, and is most useful for common deals, although not a very durable wood.

Bijasal wood is a very fine redwood and supplies the place of teak. It is easily worked, and may be safely applied to almost any purpose about a colliery, being very strong and durable. It possesses the peculiarity of seasoning as it stands in the jungle, after attaining its growth.

Eppa wood is an exceedingly fine timber, though the great objection to its use is that its excessive hardness makes it difficult to saw and work; but when once seasoned it is very durable, and may be relied upon to stand very heavy strains.

Babul wood is not much used, but the bark is very useful as yielding a large amount of tannin, and where the tree is found large it is a very strong and valuable timber.

Nulla Muddi wood is a strong-grained timber found in abundance. It is not suitable for planking as it is liable to split, but for roofing purposes and supports it is excellent.

Tiramani is a very abundant and useful tree, and supplies the bulk of the timber for underground use. It grows straight and of small diameter. It is also useful for tool and pick-handles, cart-shafts, etc.

Chinangi wood in some districts is in great favour, but in the Singareni district becomes frequently hollow after attaining full growth. It is tough and elastic, and very useful for axe-handles, buggy-shafts, and other similar purposes.

Bandari is a tree of rather large dimensions, which yields a yellowish wood useful for indoor work, but which will not stand outside or resist the attack of white ants.

Ilindu is a small evergreen tree which is used largely for pick and axe-handles.

Dudimuddi is a rather hard wood, which seasons well, takes a fine polish, and stands well in water.

Daman is a small tree used for pickaxe-handles, shafts, oars, etc., and is very tough and elastic.

Baradudi is a yellowish timber, also largely used for pickaxe-handles.

The timbers used for pick-handles, although inferior to American hickory, answer their purpose remarkably well, and are very cheap. Imported hickory handles cost, at the colliery, 10 rupees per dozen, while those made by hand from the local timbers cost only 2 rupees per dozen.

Great care is necessary to avoid the use of timber liable to be attacked by white ants, as these pests very quickly destroy the ordinary timbers of temperate climates and also many of the inferior jungle timbers. The best protection for European timber, if sent out in the form of engine-framing, etc., is a liberal application of coal-tar or creosote, but if left undressed it will be rapidly destroyed.

The local timbers described are the best and most useful available, although there is a further large variety not used, which in less favoured spots would be appreciated. Those mentioned, with the exception of gumpani, bandari, and baradudi, are very durable, and perfectly resist the white ants. They are much to be preferred to the larger and more quickly-grown teak from Burma, which is much deteriorated by being barked and allowed to season standing, thus losing its essential oils and reducing its durability. The ordinary circular saw is not of much use for working native timbers, owing to their great density and hardness. The best machine to deal with them is a deal frame-saw, but hand-labour employed in ordinary sawpits will cost about the same. Eppa, the hardest timber, costs 5 Halli Sicca rupees per 100 square feet to saw, and the softer sorts proportionally

lower rates. The workmen earn about 6 to 8 annas per day, equal to 6½d. and 8½d. respectively, and find their own saws.

Large deposits of crystalline magnesian limestone occur in the Vindhyan formation of the immediate neighbourhood, yielding very beautiful white, yellow, and blue marbles. Unlimited supplies of lime are available from these deposits, but the most esteemed building lime is prepared by burning what is known as "kunker," a limestone collected near the surface, and formed as a sort of concretion in the soil by climatic influences. This possesses remarkable binding power in buildings, almost equal to Portland cement. After a season's rain has fallen, the whole mass of work is so bound together that frequently the stone will break before the mortar. For plastering purposes, either inside or outside of buildings, it is unequalled, as it can be made to assume a polish almost equal to marble by the addition of a little talc. The flat-roofed houses so generally built in India are usually faced with the same description of plaster, and if well done in the first instance, resist the combined effect of heat and cold and rain.

The sandstones of the Gondwana measures yield a fine supply of building-stone, but no good brick-earth is found in the neighbourhood, and the Coal-measures here are without a single good bed of clay. Thin deposits occur, but these are intermittent and not available. All firebricks are purchased from England. A deposit of soapstone or talc occurs in the neighbourhood, which, if opened out, may yield a supply of fire-resisting material capable of being sawn into any required forms. It is used by the natives to make fire-resisting plates and dishes, and possibly useful crucibles might be made out of it.

There are also extensive deposits of magnetic oxide of iron in close proximity to the coal-field. The nearest of these is known as the Singareni iron-deposit. The ore occurs with laminæ of quartzite and contains in its natural state too large a proportion of silica to be practically useful. There are other deposits about 20 miles from the colliery in which the ore is purer; these are of great extent, but the district is rather difficult of access. This ore is smelted by the villagers with charcoal in small closed furnaces built of a loamy clay. The ore is free from phosphorus, and yields a splendid iron, of which they make their axes and various small articles of husbandry. There are, no doubt, the requisities of a fine iron industry here thrown together in close proximity, and awaiting only capital and enterprise to develop.

The PRESIDENT said Mr. Kirkup's paper contained much useful information, and would prove very valuable to the members. Perhaps the writer could translate the costs in Indian units into English currency, in terms such as they were accustomed to use.

Mr. J. P. KIRKUP said, with reference to the English value of the rupee, that this was such a constantly varying quantity at the present time that any calculations would prove delusive and incorrect.*

Mr. T. E. FORSTER said the relative cost of labour in a country like India, where it was necessary to employ an enormous number of men (one man producing only about ½ ton of coal per day), was interesting, and the

* The Indian currency is divided into rupees, annas, and pies. Twelve pies are equal to one anna, and sixteen annas are equal to one rupee. At the present rate of exchange the rupee is worth about 1s. 3d. The capital expenditure was calculated at an exchange of 1s. 5d. per rupee, as at the time of the transfer the exchange was higher.

result very satisfactory—when they compared the cost with the profits. He would like to ask the author whether any attempt had ever been made to work the seams on the longwall principle? It seemed to him that the manner of working in which they could most profitably employ native labour, where such an enormous amount of pit room was required, would be by having a longwall face, although it was very doubtful whether native labour could be trained to such work. He objected to the results of trials of Australian and Indian coal recorded, because some of the coals named in the table could hardly be considered as representative of ordinary New South Wales coal, and he asked that the members should not take the results as representative as far as that colony was concerned.

Mr. Kirkup said that longwall working had not been attempted in India, and after three years' experience of native labour he would not like to start longwall until the workmen had had an extensive experience, and then only under favourable conditions. He (Mr. Kirkup) had no personal knowledge of Australian coal, and he gave the results of the trials by Mr. Price-Williams upon that gentleman's authority.

Mr. G. B. Forster moved a vote of thanks to the writer of the paper.

Mr. T. E. Forster seconded the vote of thanks, which was cordially adopted.

THE VEITCH-WILSON IMPROVED LAMP-PRICKER.

The Secretary exhibited a safety-lamp fitted with the Veitch-Wilson lamp-pricker and snuffer. It is similar to an ordinary pricker, with the addition at the top of a snuffer, as shown in Fig. 1. The relative position of the snuffer is arranged so that the pricker must be raised above the ring holding the wick-tube before the snuffer can pass over the wick. The distance between the snuffer and the pricker is regulated by the construction of the lamp, so that the wick must be raised before it can be snuffed; and by so doing a fresh piece of wick is exposed and lighted by the flame before the crust can be removed. The snuffer is made of such a width as to pass over the entire width of the wick, and removes all the crust, of which only a portion can be removed by the ordinary pricker.

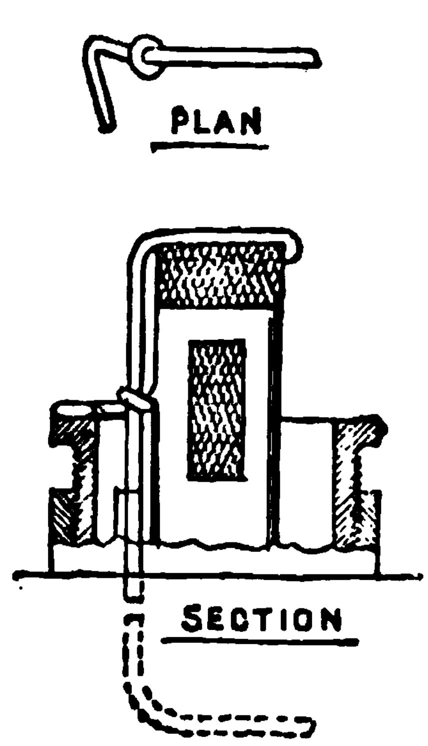


Fig. 1.

The following paper by Mr. A. L. Collins on "The Ghorband Lead-mines, Afghanistan" was taken as read:—

GEOLOGICAL MAP
OF THE
NGARENI COAL-FIELD.
(ATE OF HYDERABAD, INDIA)

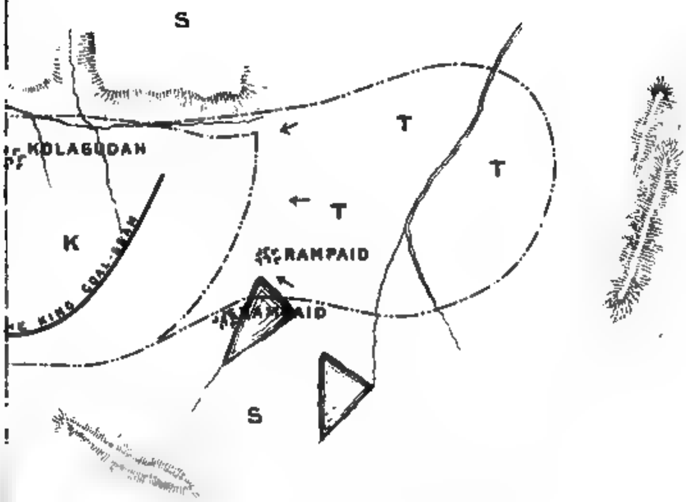
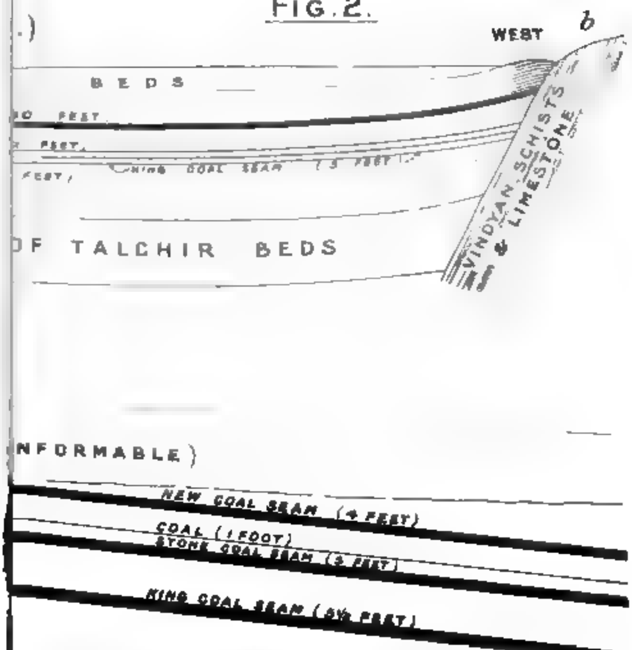


FIG. 2.



THE GHORBAND LEAD-MINES, AFGHANISTAN.

BY A. L. COLLINS.

It is perhaps natural, considering the present condition of the country, that little is known about the mineral deposits of Afghanistan; the remoteness of the country and the unsettled and suspicious nature of its Government preventing any exploitation by outside capital, or even the investigations of the ordinary traveller. There are however several deposits which have been worked on a considerable scale to supply the local demand, almost from time immemorial; among which may specially be mentioned mines of lead, rock-salt, and precious stones. Important deposits of coal, iron, asbestos, and other minerals are also known, but are at present practically unworked.

The most considerable lead-mines in Afghanistan are situated at Frinjal, in the Ghorband valley, about 50 miles in a straight line north-west from Kabul. The country around is bare and desolate in the extreme, the valley itself being 7,000 feet above the sea-level; while both north and south the mountains of the Hindu Kush and the Paghman range reach more than double that height. The climate is however pleasant; though a good deal of snow falls in the winter, it is never deep enough to seriously interfere with mining work, while grapes and almonds ripen during the summer in the more sheltered parts of the valley. The absence at the surface of waste-tips, slag-heaps, or the usual indications of the presence of mining works makes it difficult at first sight to appreciate the real extent of the operations; it is indeed possible that the openings of many of the older excavations have collapsed, or were overlooked by the writer. But judging from the extent of the old workings known—a series of large empty chambers and narrow irregular tunnels which can be followed underground for quite half a mile into the mountain—they must certainly have been worked in spasmodic Afghan fashion for hundreds of years. They seem to have been last abandoned during the unsettled times of the latest British occupation of Kabul, and were only re-opened by His Highness the present Amir some six years ago.

The country rocks are limestones and shales, striking east-and-west in about the same direction as the valley, and dipping from 10 degs. to nearly

30 degs. northwards. The age of these rocks has not been definitely fixed, the only fossils found by the writer being a few imperfectly preserved crinoidal stems, too fragmentary for recognition; but they are probably as old as, or older than, the Carboniferous. The lead occurs in a large fissure-vein, having roughly the same strike and dip (15 degs. north) as the enclosing broad belt of limestone; the ore forms the cementing-material of a breccia composed mainly of angular limestone-fragments, varying in size from the smallest piece up to large blocks many tons in weight. (Fig. 1, Plate XIII.) Closely examined, the ore is found to be finely crystalline galena, with small patches of iron pyrites, and a little crystalline calcite, the whole being sprinkled confusedly through buff marly clay which fills all the interstices between the limestone-fragments: no galena clean enough to smelt without previous washing being found in the mine. In places a tendency towards a concretionary structure of the galena is noticed in the clay (see lower part of Fig. 1), which suggests the much more perfect little concretions of galena in the soft sandstone at Mechernich, Rhenish Prussia. It is noticeable that the larger limestone-fragments are often surrounded by a thin edge of brighter clean galena, as if they had determined the deposition of the lead from solution—just as gold in the Barberton conglomerate is often deposited as a crystalline film around the larger pebbles.* The brecciated fragments seem to be in actual contact with each other, as if they were all in position in the fissure before the advent of the lead-carrying solution; and though large surfaces of fine-grained galena and clay, up to 30 or 40 square feet in area, are often met with in the working-faces, it is only where the fragments of the breccia are themselves large, or against the hanging wall of the deposit. The vein is very wide in places, some of the workings measuring over 30 feet from wall to wall; but there is a remarkable absence of cavities, and of crystallized minerals; even secondary calcite, generally so common in such deposits, being comparatively rare. Nor is there any evidence of repeated re-opening of the original fissure; the large amounts of marly clay found on some parts of the footwall, and mixed with the galena itself, being probably due to the forces which originally caused the shattering of the limestone in the fissure, and the subsequent partial solution of the impure limestone. This idea is supported by the appearance of the limestone-fragments in the breccia, which are found on breaking to consist of unaltered hard bluish limestone in the middle, with a softer, whiter, and more decomposed envelope outside. There are many mineral springs in the immediate

* Mr. C. J. Alford, "The Geological Features of the De Kaap Gold-fields," *Mining Journal*, 1889, vol. lix., page 475.

neighbourhood, apparently on the lines of fissures, which are now depositing huge masses of travertine at the surface; the water being cold, faintly alkaline, and highly charged with carbonic acid gas. It is possible that such a spring of alkaline water originally deposited the galena in the Ghorband lode, dissolving out some of the pure carbonate of lime and leaving the insoluble clay behind; and that if the travertine caps of the existing springs could be removed it would be found that similar ore deposits are even now in course of formation.

The lode weathers at the surface to a well-defined ferruginous gossan, the lead disappearing, and the pyrites being decomposed so as to colour all the cementing material between the limestone-fragments: the brecciated nature of the whole being still distinctly visible. This gossan can be traced at the surface for over a mile, and seems to have been worked upon in several places; a few small specimens of cerusite were found in it by the writer, who was informed by the workmen at the mine that considerable amounts of that ore had at one time been treated.

The mine is worked by the Afghan Government, a colonel from the army being in charge, at a salary equivalent to about £2 10s. per month. This official has, of course, no knowledge of mining; he was, in fact, much disgusted at being required to accompany the writer underground; but judging from the style he keeps up it is obvious that he has some other means of supplementing his income. There are about 600 men kept working, half by day and half by night; and they are drawn in rotation from 1,800 men of the whole district for 30 or 40 miles around, each man serving ten days at a time. These men are all Hazaras, a race of small and active men of Mongolian type, who make cheerful and hard-working miners; a small guard of Afghan troops being, however, kept at the mines to prevent disturbances. The men agree among themselves where and how to work, each gang of ten choosing a *dah-bashi*, or foreman, to arrange such matters, and to receive and divide the pay. The ore has to be brought out of the mine, crushed, and washed clean, ready for smelting, by the miners themselves, being paid for at the rate of one Kabuli rupee for four seers, or about 35s. per ton of 2,240 lbs., out of which deductions are made for steel and oil. If fairly paid this would give something under 1d. per day to each man, as against the 3d. or 4d. which would be the proper pay, *e.g.*, of a soldier, but they are often cheated even of the balance fairly due, by the Afghan scribes and officials; so that even the "tail of the cow," as they pathetically put it, is withheld from them. As a matter of fact, all seemed to bring their food with them to the mines when they arrived for their ten days' service, putting very little faith in the possible pay.

The mine, which is quite free from water, is approached by an incline from the hillside, with a slope of about 15 degs., which seems to follow pretty closely the footwall of the vein. This soon opens out into a great chamber, over 54 feet long and 18 feet high, quite one-half of which is metalliferous cementing-material, and which at present yields nearly one-half of the ore obtained. Other workings ramify, up or down, in every direction from the chamber. All work is done with hammer and gad—a short-handled hammer of about 2½ lbs. weight, often little more than a cubical or somewhat oblong lump of iron, with a hole down the middle for the hilt, and a steel gad of from 5 to 10 inches in length, being commonly used. This practically precludes working in the hard limestone, so that the old workings show the approximate shape of the ore-bodies formerly met with. They are of necessity extremely irregular, varying from what are no better than rabbit-burrows, along which it is difficult to crawl lying flat, to large irregular chambers, which fortunately keep open without timber or stowing.

When any exceptionally large mass of limestone is met with in the breccia, the ore all round has to be laboriously dug out, and the boulder left underground, but with this exception, everything broken is taken outside for treatment—no very difficult matter where each man breaks only a few pounds of stuff per day. Recently, blasting with gunpowder has been introduced in a few cases, to break particularly troublesome masses of waste rock; the holes being bored by ordinary jumpers. But the Hazara miners are not paid for deadwork and dislike the extra expense; and the Afghan officials perceive that the price paid for the ore could hardly be lessened, even if gunpowder were provided free of charge, so it is not much used at present.

The miners' lamps are of baked clay or dug-out steatite, of the old open Roman pattern, and are carried in the hand or rested on projecting corners of the rock: cottonseed or mustard oil being burned, with a wick of cotton rag. The writer, with his assistant, Mr. Henry Middleton, and the native officials were provided with torches, formed by wrapping oiled rag around a short stick. No attention is paid to the ventilation, so that in places where narrow and tortuous leaders (a foot or so in width) are being worked the heat is great and the air very foul. But the miners do not seem to suffer in health, as they arrange so that no man works for long in the worst places. Moreover, the 20 days of freedom between each 10 days of work gives time to recoup, as well as to cultivate the land around their villages, on which their living depends. In one part of the ancient workings an ingenious contrivance for improving the

ventilation was noticed: the incline from the surface being made double, with a narrow bar of ground between, pierced at intervals as required.

No account is kept of the amount of stuff broken underground; but the amount of washed lead-ore bought daily by the smelting-works is about 30 cwts.; and, estimating that this represents four times its weight of stuff brought out of the mine, it appears that each man only breaks 20 to 25 lbs. of stuff per day—an amount surprisingly small, even when the toughness of the ground, the inferior tools, and the extreme narrowness of many of the workings are considered. It must, however, be remembered that each man has to crush and wash, as well as to break, his own ore.

Little or no handpicking is possible, so the ore brought out of the mine, which is already mostly in small pieces, is crushed by hand: a large stone being used as a pestle, on a flat beaten bed or another flat stone. It is then panned in a smooth wooden dish of about the same shape as an ordinary gold pan, but somewhat smaller (about 1 foot in diameter); the lighter waste, together with most of the slime galena, being washed away and lost. There is a certain amount of middle product, which is crushed and washed over again; but most of the concentrate is galena, fairly free from limestone and clay, but contaminated with a considerable amount of iron pyrites. It assays about 68 per cent. of lead and 1½ ozs. of silver per ton.

Small amounts of lead-ore are also obtained from the Chilan mines among the rough hills a few miles to the south of the Ghorband valley. The rocks here are clay-slates and siliceous grits, lying nearly horizontal: these being cut through by many narrow veins, striking north-west and dipping 70 to 80 degs. south-west, corresponding to one of the jointings of the grits. These veins are generally only a few inches wide, the vein-filling being solid, large-bladed galena, with angular fragments of the country rock. The richer parts of the veins are followed up or down, wherever they may lead; and the workings are, in consequence, so narrow and tortuous that it is often most difficult to crawl or squeeze along them. The only tools used are hammer and gad, so that a pinch in the hard rock is an effectual bar to further progress; and for the same reason cross-cutting underground is unknown, though some of the veins are only 2 or 3 fathoms apart. The writer saw work being done on a vein less than 2 inches in width: some of the slaty wall-rock being perforce taken with the vein-stuff; but the average would perhaps be 6 to 8 inches. In a few places, especially where the rock is siliceous grit, and the workings have an upward trend, the old process of fire-setting is used: fires being lit against the face so that the flames play upon the rock, and cause it to split off in

flakes. The mines being at an elevation of nearly 10,000 feet, there are no trees, and the only fuel obtainable is dried camels' dung, and a small prickly bush, which is common on the stony mountain-slope, and which burns so quickly that it has to be continually replenished. The main objections to the process are the heat and smoke, all products of combustion having to find an outlet by the same tortuous channel, often less than 3 square feet in cross-section, by which the men enter. The ore is brought to the surface in skin bags, which are pushed or pulled along by the miner.

As already stated, the washed ore is bought from the miners at the rate of 3d. per 16 lbs., or about 35s. per ton; and it is smelted under the direct supervision of the Afghan officials, by men who give their whole time to the work, and are paid at the comparatively high rate of about 4d. per day. It is done in very small furnaces and at widely scattered centres, on account of the difficulties of procuring fuel: the six furnaces at the mine treat only a quarter of the total output, and are considered mainly as a means of controlling the quality of the washed ore, assaying being unknown. The furnaces used resemble the Scotch hearth in principle, and are very simple in construction. A rubble wall, 5 feet long, 5 feet high, and 18 inches thick, is built along the hillside, in a position best adapted for carrying off the fumes by the wind, and a rough roof is carried from the top of the wall back to the hillside to shelter the workmen producing the blast (see Fig. 2, Plate XIII.). The actual furnace is a rounded cavity in the bottom of the wall, lined with refractory steatite-clay, 18 inches by 14 inches by 7 inches, of the form shown in the sketches (see Figs. 3, 4, and 5, Plate XIII.), and it is worked entirely from the front. There are two tuyères of clay, $\frac{3}{4}$ inch in diameter; the blowing apparatus being two sheeps' skins, each fixed to a tuyère by the neck and split open at the other end. The split ends of each skin are turned around two sticks of wood, by which they can be grasped, and opened or closed with one hand. A workman sits between the skins, taking one in each hand, and forcing them alternately backwards and forwards, the split ends being opened on the back stroke and closed when the extended skin is being forced forwards again, thus producing an intermittent or pulsating blast. The work is so hard that two men are necessary to keep a furnace going, relieving one another at short intervals. It is characteristic of the Afghan want of ingenuity that although there is ample water-power in the valley close at hand, this cumbrous and inefficient method has never been improved upon.

The charge of a furnace is 20 lbs. of ore, which is thrown damp into

the hearth, still hot from the last charge, and a few sticks of wood are thrown in on top. The fuel used is exclusively dry soft wood, such as poplar and willow; harder woods like oak, mulberry, and walnut, being said not to answer. It is split into pieces, 10 inches or 1 foot long, and 1 or 2 inches thick. When these have kindled, a gentle blast is started, more wood being constantly added, and full blast quickly got up. The ore is frequently stirred and worked from the front with a thin poplar branch, and it is always covered with more or less wood. The flames and smoke come out in the front, much lead being lost in the fumes, which coat the front wall with yellow and orange incrustations and the ground around with fine, grey smoke; and, as is to be expected, the workmen suffer a good deal from lead colic. In 1½ to 2 hours the smelting of a charge is finished, the lead being reduced and the molten bath covered with a dry sinter in small lumps, containing many metallic shots. All is now scraped down with the stick, and the slag repeatedly and thoroughly stirred into the molten lead. Then the blast is stopped, the slag is scraped out, and the lead is ladled with a shallow iron ladle into little rounded depressions in the ground; the hearth being at once cleaned, when it is ready for a new charge of damp ore.

Each furnace smelts six such charges, or 120 lbs. of ore, per day of 12 hours, and it is worked by four men—one smelter, two blowers, and a man who assists generally by splitting wood, etc. Each charge (20 lbs.) of ore requires 24 lbs. of dry wood, and yields 7½ lbs. of good soft lead, or 37½ per cent. out of 68 per cent. present. The balance is lost in fumes and in the slags, for although the latter are crushed and washed for metallic shots, they still contain as thrown away nearly 50 per cent. of combined lead. The ore from the Chilan mines is nearly pure galena, with quite 80 per cent. of lead; but when crushed and smelted in the same way it yields only half its weight, or 50 per cent. of metal. This ore contains from 15 to 20 ounces of silver to the ton, but so little is mined that it is disregarded—indeed the separation of silver from lead does not seem to be known to the Afghans.

The total cost of a ton of smelted lead from these mines is therefore as follows:—

	£	s.	d.
Mining, crushing and washing 2⅔ tons of clean ore at 35s. per ton	4	13	4
Smelting—Labour, 1s. 3d. per 45 lbs. of lead ...	3	2	3
Fuel, 144 lbs. wood per 45 lbs. of lead ...	2	4	3
Superintendence, etc.	0	10	2
Total cost per ton of lead	£10	10	0

The total output being about 14 tons of smelted lead per month.

There are probably few places in the world where so many men are at work with so trifling a result, and at first sight no better field for the introduction of improvements could be found. But the introduction of European methods of mining would be impossible for political reasons. At present the Hazara miners consider the mines to be their own property, where they can work how they please, being bound only to extract a certain amount of ore at a fixed price, and any interference with the system would be resented. Moreover, European methods would mean the creation of a body of skilled men in constant employment, who would have to be paid a living wage of say 4d. per day, and so the cleaned ore could probably never be obtained for less than the present very low figure. It is true that the output could be vastly increased, but these and other mines already produce enough for the needs of the country, almost confined to the making of bullets; and there is a disinclination to export metal. Probably the most practical improvements in Afghan mining would be the introduction of the Cornish poll-pick, and the extended use of blasting for breaking the harder and narrower parts of the lode; while simple machinery could easily be made locally for crushing and dressing the ore, so as to avoid most of the present loss in slimes.

But it is in the smelting that the greatest economies could be effected. By increasing the size of the hearths and using a water-power blast the present absurd expenses of labour and fuel could be lessened; and with flues to condense the fume, and a slag-hearth to re-smelt the slags, a fairer percentage of metal might be saved. Brushwood is fairly cheap and abundant, so an adaptation of the smelting-furnaces used at Linares in Spain might be even more successful.

It will be understood that the unsettled political condition of the country has as much to do with the backward condition of mining as the ignorance of the people. There is evidence that things were not always so bad as they are now; thus, small amounts of fused slags, poor in lead, found at the surface, show that smelting was at one time better understood. But no ruler latterly has been sure enough of his position to give much attention to mines, and a class of professional miners would fare badly in time of war. It is only as the country becomes more settled politically that the mining industry will be likely to improve.

The following paper by Mr. A. G. Charleton on "The Choice of Coarse and Fine-crushing Machinery and Processes of Ore Treatment, Part VI." was taken as read :—

To illustrate Mr. A. L. Collins' Paper on "The Ghorband Lead-mines, Afghanistan"

FIG. 1.

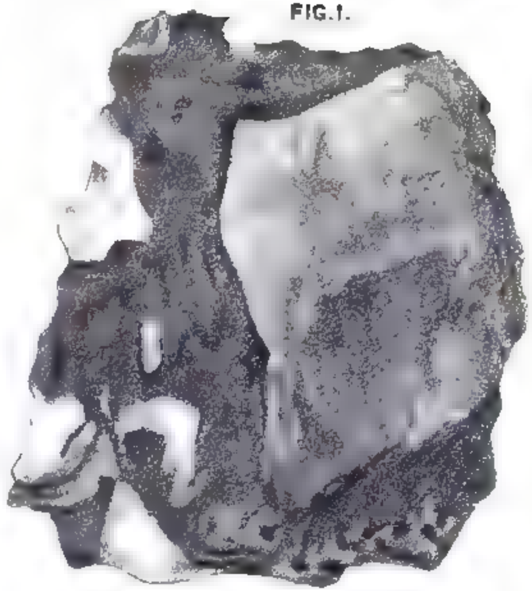
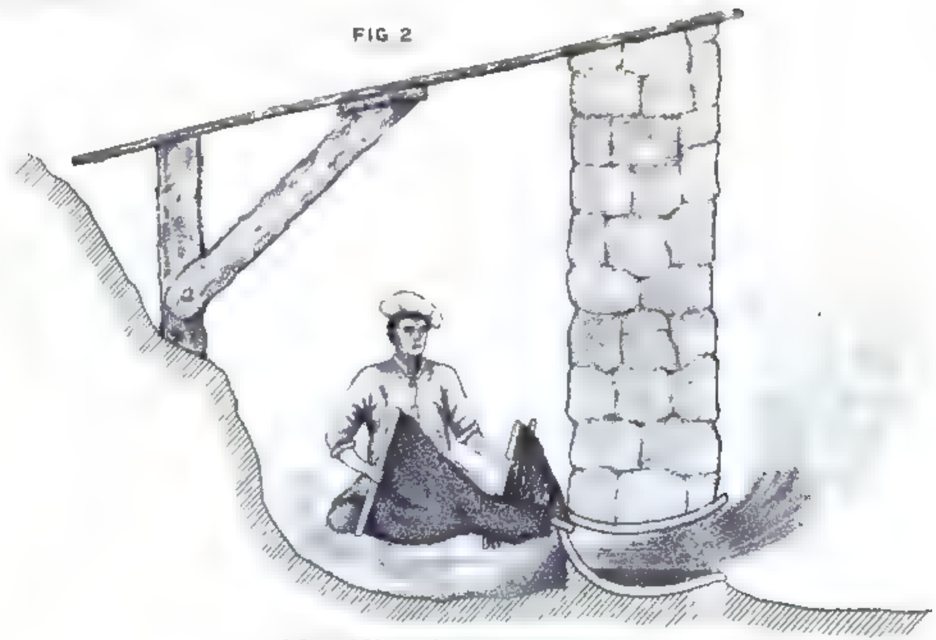
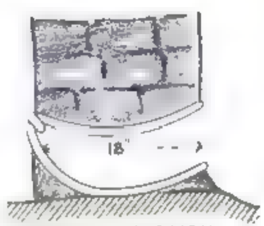


FIG 2



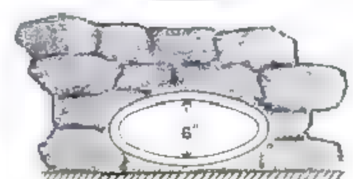
SIDE ELEVATION (PART IN SECTION)

FIG. 3.



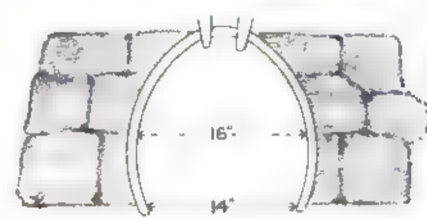
VERTICAL SECTION.

FIG. 4.



FRONT ELEVATION.

FIG. 5.



PLAN.

THE CHOICE OF COARSE AND FINE-CRUSHING MACHINERY AND PROCESSES OF ORE TREATMENT.*

By A. G. CHARLETON.

PART VI.—GOLD-MILLING.—*Continued.*

PRACTICE IN DAKOTA.†

The gold of the district is found in quartz and pyrites finely distributed through vast masses of mica and amphibole-schists, argillites, and phyllites, and also impregnating the schists themselves. The gold-belt embraces the sections of Lead City, Terraville, and Central City. The principal associated mineral is iron pyrites, with some arsenical pyrites, garnet, and asbestos.

The ores from open cuts and the upper levels are more free-milling than those from the mine workings below the water-line. Hence the mills running on oxidized ore have tailings valued as low as 1s. 0½d., while tailings from unaltered ore run up to 9s. 4½d. per ton. By watching the pulp when it flows down the plates, it can readily be determined whether it comes from the higher or lower levels. In the former case it will generally have a brownish-red colour, and in the latter it is of a bluish-grey. The amount of free gold in the ore varies with depth, and probably 16s. 8d. per ton is a near average of its value.

To determine the amount of free gold in the ore the following method is practised:—Samples are taken daily from the various workings in the mine and sent to the sampler, who crushes and pans them and estimates the gold in each pan. Every valuation thus made is booked, and at the end of the month the average is taken, and compared with the output of the mill, and the amount of gold recovered thus approximately determined. The mode of operation practised by the sampler is very simple. The sample, weighing say 10 pounds, is emptied into a 4 gallons bell-shaped mortar (13½ by 12½ inches). From it 2 pounds are then

* *Trans. Fed. Inst.*, vol. iv., pages 233 and 351; vol. v., page 271; vol. vi., pages 69 and 295.

† The writer is largely indebted in this section to a paper by Mr. H. O. Hofman, on "Gold-Milling in the Black Hills."—*Trans. American Inst. Min. Eng.*, vol. xvii., page 498.

transferred into a second mortar of the same size with a wooden lid, and pulverized wet to a fine pulp by means of a small steam stamp, which is in reality an old power-drill fitted up for the purpose. When sufficiently fine (as judged by the ring of the pounding-stamp) the pulp is panned until all the pyrites and heavy sands are washed off with the tailings, and only the free-gold remains behind. The sampler of the Homestake Company pans from 50 to 55 samples per day. Great skill is acquired in thus estimating the value of the ore, the sampler being able to make eight or ten valuations per hour. As these are the only determinations made, the amount of non-free-milling gold which enters the mill is not known.

The percentage of sulphides from several determinations that have been made varies from 2½ and 3 to 6 and even 10 per cent. The assay value of pure concentrates freed from rusty gold, or gold included still in the quartz, has been shown to vary from 16s. 8d. to £16 17s. 6d., the average being about £5 4s. 2d. per ton.

As the ore is finely disseminated throughout the entire vein-matter, comparatively little sorting can be done in the mine. There occur, however, in many parts of the veins igneous intrusions, locally called porphyry, which form barren horses. When the Nevada system of timbering in square-sets was exclusively in use no distinction was made between mill-rock and waste, but it was considered cheapest to run it all through the mill. Latterly, however, it has become the custom to fill the chambers formed by this timbering with waste, and to hoist the excess to the dump; but large quantities of it are still crushed.

The auriferous lodes and gravels were discovered in this district in 1876, when a rush to the Black Hills took place.

The seven principal mills are the Homestake, Golden Star, Highland, Deadwood, Golden Terra, Father de Smet, and Caledonia. The first six are owned by five separate companies, but are all under the management of the Homestake mill superintendent, and all the working details are much on the same model. The Caledonia mill works on different rock, and differs from the others in details of plant.

The crushing is all done by rock-breakers and stamps. The ore arriving at the ore-floor at the highest level of the mill is discharged from side or bottom-dump cars over grizzlies, which divide it into lumps (going to the breaker) and fines (falling into the bins). The lumps are crushed in the rock-breakers and join the fines, and the mixed product, passing through shoots, goes to the automatic feeders, which deliver it to the stamps.

The Caledonia mill has blankets on the lower end of the apron-plates, below the copper plates, to catch any coarse heavy particles. In the other mills the pulp passes direct from the apron-plates to the mercury-traps, and through them on to sluice-plates. From the traps placed at the end of these the pulp runs into one main sluice, which may have again one or more mercury-traps before the pulp is allowed to finally run to waste.

Amalgamation begins in the mortar (which is provided with inside copper plates, mercury being added to the box at intervals), and is continued outside on the apron-plates; any mercury or amalgam escaping these appliances being caught in the mercury-traps* lower down, which are used to supplement them.

The aim in Dakota is to crush rapidly to the desired degree of fineness and arrange the amalgamation so that it shall be adapted to the large amount of pulp produced. The distribution of power in the mills is of three different types, represented respectively by the Homestake, Golden Star, and Highland mills.

In the Homestake mill the continuation of the engine-shaft forms the one-line shaft of the mill, and is placed on the battery-sills. This is a cheap construction, and gives a solid foundation for the boxes in which the line-shaft rests. The shaft is kept in line by the even pull of the long belts on each side of it, running at an angle of about 30 degs. between the bins in the centre of the mill. The disadvantage of having to stop the mill if anything happens to the line-shaft may be dismissed as insignificant. For minor repairs, however, it is in an obscure place, running behind the batteries.

In the Golden Star mill the power is transferred from a small main shaft to two line-shafts on the cam-floor, which is nearly on the same level. This arrangement is usual in Pacific coast batteries.

In the Highland mill the small main shaft is placed between the cam-floor and the battery-floor, and is connected with two line-shafts† placed on the battery-sills behind the mortars, which are set back to back with the bins between them. Two lines of shaft are used, in consequence of the power required for a 120 stamp. The disadvantage is that the pull of the belt on one side only of the shaft, has a tendency to drag it out of line and cause excessive wear and tear.

* An illustration of this apparatus will be found in the *Eighth Annual Report of the California State Mineralogist*, page 711.

† These are coupled up in sections, 7 inches in diameter near the engine, reduced at the opposite end to 4 inches.

As to placing the line-shafts in front of the batteries on the cam-floor (as in the Golden Star mill), or behind them on the battery-floor (as in the Highland), there is a diversity of opinion. The former arrangement gives the best light, and makes the shafting easily accessible. The power from the engine-shaft is transmitted to the line-shafts, and from these to the cam-shafts by horizontal belts which require no tighteners and last longer. On the other hand, the boxes of the line-shafts rest on traverse sills on the cam-floor which, although braced and otherwise strengthened, do not afford as solid a foundation as when fixed on the battery-sills. On the whole, however, this disadvantage appears more than counterbalanced by their greater accessibility and the smaller wear and tear of belting.

On the battery-sills behind the mortar, the line-shaft is in darkness and exposed to the trickling of water and the abrasion and dirt of fine ore falling from the feeder-floor, whilst the belts connecting the main and line-shafts and the latter with the cam-shafts, are short and highly inclined, requiring powerful tighteners.

The relation of the horse-power of the engine to each stamp averages about 1·7 to 1 for the seven mills. This low figure is due to the large number of stamps in each mill (80 to 120) which is much above the ordinary number.

The Father de Smet mill is built with the batteries on opposite sides of the building face to face, an arrangement which is said to have the disadvantage of rendering it rather dark.

The Golden Star and Highland mills have each 120 stamps, and the Father de Smet mill 100 stamps of 850 lbs., dropping 85 times per minute, with a fall of 9 inches, arranged in batteries of five. The Homestake, Deadwood, and Golden Terra mills have each 80 stamps, with the same weight of stamps and height and number of drops. All these mills crush on the average about the same weight of ore per stamp head, viz., 4·5 tons per 24 hours. The Caledonia is a 60 stamp mill with 850 lbs. stamps, dropping 12 inches, 74 drops per minute, and it only puts through 3·3 tons of ore per 24 hours.

The water supply is furnished by ditch companies at 50 to 57 cents per stamp per diem. A regular supply is an essential for milling. When it becomes scarce in winter it is supplemented by pumping from the Homestake and Deadwood Terra shafts.

The Highland mill would be obliged to stop four months each winter if the tailings of the Homestake, Golden Star, and Highland mills were not settled and the clear water pumped back into the mill supply-tanks. The

method by which this is done is of interest. The tailings of the three mills named are discharged into Gold Run creek. A little way down, where the creek broadens it is closed by two dams, one below the other, forming an upper and lower reservoir. The former overflows into the latter, which is four times its size, and this in turn overflows into the bed of the creek. The dams consist of cribbing filled with waste rock, lined on their upper sides with planking to make them watertight. Down the middle of the face of the upper dam runs a wooden box or launder, three sides solidly planked, with the fourth open; when the reservoir is to be filled the box is closed by heavy transverse strips of planking. The object of a number of pieces is to discharge the water gradually, which is done by removing the pieces one after the other as the water is lowered, so that the sands may be kept in suspension and carried through the culvert. Were the box open from the bottom or to its full height at once, the sands would be carried into the culvert in such quantity as to close it. This culvert in which the box ends, passes through the dam and under the large reservoir and lower dam to the bed of the creek below. The lower dam is arranged in the same way. When the reservoirs are not in use the water of the creek passes off through the culvert. When they are to be filled the boxes are closed, and the water accumulates in the upper reservoir until, after 6 hours, it overflows, leaving all the coarse sands in the upper reservoir, and carrying only the finer slimes, which settle in the lower one. From this the clarified water is pumped at the rate of 60 cubic feet per minute into the Highland tank 200 feet higher.

The coarser sands are removed from the upper reservoir every 24 hours. In order to do this the traverse planks closing the discharge are removed one after another, and the water passes off, carrying the sands with it. As this process takes 4 hours, and the filling 6, there are 14 hours of overflow into the lower basin, where the slimes settle. These are removed once in two months in the same way.

In Queensland, Australia, where water has to be rigorously economized, a reservoir is frequently built in a suitable position at the side of a creek, so as to enclose a large area. Openings are then made in the artificial embankment which takes the place of one bank of the creek, and lock-gates are thrown across the stream forming an extension of the embankment at the lower end of the reservoir. In the rainy season these gates are closed temporarily so as to raise the water to the level of the openings in the embankment, through which it finds its way into the reservoir until the latter is filled. The water accumulated in this way is used as a

reserve in the dry seasons, at which time, if the sides of the creek are abrupt enough to admit of doing so, large dams of sand formed of tailings may be thrown across the bed of the stream to back up any water that can be accumulated behind them. The accumulated tailings are washed away in the rainy season when the flood-gates are opened. The water, notwithstanding that it carries considerable silt, has often to be used over and over again by pumping it from the reservoirs with a tailings-pump, which, in order to prevent the plunger from being cut to pieces, has a small stream of water introduced under pressure by a small pipe into the plunger-case.

In some Queensland mills, the system adopted is to construct a breast-dam running right across the creek, with a gate in the middle through which the silt which accumulates, partly in times of flood, partly from settling the tailings, can be flushed out. At the end of the rainy season, it is filled with water, and the mill draws its supply from this reservoir by means of a pump. The mill-tailings are discharged immediately below the reservoir through box-launders put together in short sections, the lower end of one entering the top of the section below. After a heap of tailings has accumulated against the back of the dam, at the side of the creek over an area of 5 or 6 square yards, an accumulation which can be facilitated by changing the position of discharge of the launders, the flow is diverted to one side until the heap has drained and settled enough to allow of a shallow pit about 1 foot deep being dug in the surface of the heap (which is roughly levelled), leaving a wall of sand (tailings) round the edge. The mill tailings are then allowed to run into this temporary basin, and the sands settle in it, whilst the partially clarified water is returned by a short launder through a hole in the face of the dam (near the top) into the reservoir. Whilst the first basin is being filled up, the tailings-man is engaged in digging out a second one at the side of the first, into which the tailings are diverted when the first one becomes partly filled with sand. The heap forming the foundation of the basins is constantly extended outwards by throwing with a shovel the sand from the basin to the outside of the wall of sand, which forms a natural talus sloping outwards. It is of the greatest importance when this method is used to keep the level of the basins as high as possible, with a slight rise outwards as they are extended into the creek, otherwise the water cannot circulate backwards at a sufficiently high level to enter the reservoir at the point where the opening is made for this purpose.

The fuel for the mills of the Homestake management is supplied by the Black Hills and Forte Pierre Railroad Company. This road, with

about 30 miles of 3 feet gauge track, runs along the divide between Gold Run and City Creek, terminating at a point about 14 miles south of Lead City. The whole section was originally heavily wooded, but has been quite denuded by the constant demands made upon it. The railroad is very winding, and is quite a feat of engineering. It runs down the slope into Whitewood Creek and up the opposite height, till it finally reaches the point where timber is still to be obtained. This road, as soon as it is open in the spring, is employed in transporting the timber which has been cut and stored along its line, and is in constant use till it becomes blocked with snow, generally from January till April. It has three branches towards the three towns where the mills are situated, and communicates directly with these by long wooden shoots, down which the timber is discharged. These shoots are 700 to 1,500 feet long, running down the slope of the mountain, they are 25 inches broad by 12 inches deep, and are made of 4 inches planking. The bottom and 9 inches of the sides are lined with ¼ inch iron plates. The fall of the shoot is 6 inches to the foot until the curve begins, when it is 4½ inches. This continues to the nozzle, which is elliptical. When the shoot is in use a small current of water is passed through it, to prevent the iron from becoming too hot and to act as a lubricant. The cord wood unloaded at the top of the shoot passes down the incline with great velocity. At the nozzle it is deflected from its course, and through the momentum obtained in the downward passage it shoots up into the air and drops some distance off on to the wood-pile. In order to discharge the wood on a large area and to stack it, the nozzle is made movable.

The price of wood in the district is £1 5s. per cord. The water is warmed, as elsewhere mentioned, to keep it from freezing in winter, and fireplugs with hose-attachments are placed at intervals in the mills as a safeguard against fire.

To reduce the cost of repairs, which is a heavy item, the Homestake Mill Company has a foundry where rock-breaker shoes and dies, pitmen and toggle-plates, mortars and dies, boss-heads, tappets, thimbles for fingers, cams and hubs of cam-shaft pulleys and shaft-boxes, etc., are cast from Nos. 1 and 3 foundry-iron and worn-out castings. The castings are made in sand, with the exception of the rock-breaker shoes and dies and faces of battery-dies, which are chilled. All the necessary repairs are executed in the machine-shop, which is a very complete establishment. The six Homestake mills use the same patterns for all parts requiring frequent renewal, which reduces the amount of material kept on hand, and labour and cost of repairs.

The Grizzlies relieve the rock-breakers of the ore which does not need crushing. They are 3 to 4½ feet wide, 10 to 14 feet long, and set at an angle of about 40 degs., or a rise of ⅞ inch per foot. They are made generally of wrought-iron* bars 1 inch wide and 2 to 4 inches deep, held 1½ to 2 inches apart by three or four, sometimes five, 1 inch iron rods, provided with thimbles at proper intervals to keep them apart. The Father de Smet grizzlies, which are 4½ by 12 feet, with 24 bars 1 inch by 2 inches set 1½ inches apart, weigh 2,040 lbs. The grates last about four years.

Rock-breakers.—No. 5 Blake rock-breakers are mostly in use, with jaw (opening 9 inches by 15 inches) set to crush from 1¼ to 1¾ inches, run for 20 hours out of the 24 ; this size is calculated to serve 20 stamps. If one-fourth of the ore passes through the grizzlies and 20 stamps crush 90 tons in 24 hours, the amount crushed by one such Blake breaker in 20 hours is 67½ tons or 3·4 tons per hour. This small figure as compared with the nominal capacity of the crusher, *i.e.*, 7 tons, is due to the delay in breaking up the ore so as to enter the jaws. The advantages of the Gates crusher in this respect have been previously mentioned. The No. 6 Gates crusher in use at the Caledonian mill is said by Mr. T. L. Skinner, the superintendent, to have saved him £5 12s. 6d. per day.

Mr. Hofman advocates for a large mill a still larger Gates crusher (No. 8 with receiving openings 18 inches by 48 inches), set to crush coarse, discharging into two No. 6 crushers set to crush fine. Thus the largest pieces of rock that any man could handle would pass direct into the crusher without hand-breaking.

Ore-bins.—The ore-bins are triangular in section, with one vertical side facing the battery and reaching down to the cam-floor. Just above the latter are the openings (one for each feeder) through which the ore passes down into the shoots terminating in the hoppers of the feeders. The discharge can be regulated by a sliding-gate, with a rack worked by a pinion keyed to the shaft of a small hand-wheel. In a double mill the inclined bottoms of the two bins diverge, leaving an open space between them having the shape of an inverted V. The bottoms of the bins, 3 inches thick, are made of 1 inch board, running lengthways, with 2 inches planking set crossways on them, but this is not the best arrangement. The bottom and sides are strongly braced with timber. The upper part of the bottom on which the ore drops from the grizzlies and crushers is

* Hard cast-iron is being introduced for this purpose in some mills.

lined with iron to prevent it from wearing out faster than the lower parts, which last five to six years. There are no compartments or divisions to direct the ore to the discharge-openings, as they are unnecessary. Ore-bins should be given as large a capacity as possible, so that, in case of accident at the mine or to the rock-breaker the mill need not be stopped. The Highland mill has the largest bin capacity of the group under review, except the Father de Smet mill. In the Highland mill the horizontal distance between two sets of batteries is 46 feet, and the vertical height is 22¾ feet. In the Father de Smet the apron-plates are overshadowed by the bottom of the bins, which neutralizes the advantage of facility of supervision claimed for this arrangement, by rendering the building dark.

Feeders.—The feeder may be arranged so that the lip of the feeder reaches into the feed-slit of the mortar, but at the Caledonia mill they discharge with a small inclined iron-lined apron which leads to the mortar. By this arrangement a little more room is left between the feeder and mortar, and the feed-opening can be longer and narrower, distributing the ore more uniformly under the stamps. The Homestake mill mortar feed-opening is 24 inches long and 4½ inches wide, while at the Caledonia it is 52 inches long and only 3 inches broad, occupying the whole length of the mortar. The Hendy Challenge and Tullock automatic feeders are in use, the Challenge feeder being the most desirable for wet ores.

Both right and left-hand feeders are used, the bumper-rod standing between stamps 1 and 2 or 4 and 5. Some of newer pattern are made with the bumper-rod next the central stamp (central feeders). The rod is guided from the cam-floor, passing through a hole in a board fixed to it. The sheet-iron plate below the Tullock feed wears out quickly (with Homestake ore in two years), but is cheap and can be patched or renewed by a blacksmith. The circular cast-iron carrier-table of the Challenge feeder lasts seven years with the same class of ore, but is costly; and if anything goes wrong with the gearing, it requires a fitting shop and machinist for its repair.

Foundations, etc.—A good foundation is the starting-point of every piece of good engineering work, and nowhere is it more necessary than in a stamp-battery. A rectangular pit, 11 to 14 feet deep, is excavated to receive the mortar-blocks, made sufficiently long and wide (4 feet by 6½ feet) to leave a space of about 24 inches round the block. The bottom is then carefully levelled and some sand tamped down, or concrete is run

in. On this are placed two layers of 2 inches planks, spiked cross-wise to each other, and then the planks which form the mortar-block. The latter used to be placed in the pit, and the uneven tops were afterwards sawn off level. Now care is taken that this 4 inches wooden floor shall be accurately horizontal, and that the distance between it and the bottom of the mortar shall correspond with the length of the mortar-blocks. The top of the block is planed. By employing this flooring the time required to replace a mortar-block is reduced from six or seven days to five.

The mortar-blocks used in Dakota consist of planks from 11 to 14 feet long, depending on the depth of pit, of varying width, and not more than 2 or 3 inches thick, as it is difficult to find wood of greater thickness and yet sound throughout. They are spiked together, and fastened above and below with binders bolted to each other by transverse rods, the upper binders (8 by 12 inches) being even with the top of the mortar-block, and the lower binders (12 by 12 inches) 3 feet lower down. The space round the block is then carefully filled with rock and tailings up to the level of the mud-sills, which are about 4 feet below the bottom of the mortar. When the top of the block has been planed off level, a sheet of rubber-cloth $\frac{1}{4}$ inch thick is placed over it and the box put in place. Through the four holes in the flanges on each side pass 8 bolts from 3 to $4\frac{1}{2}$ feet long, and $1\frac{3}{8}$ to $1\frac{1}{2}$ inches in diameter, by which the mortar is held down.

In placing the planks forming the block and adjusting the holding-down bolts an improvement has been introduced at the Homestake mills. The planks which always stand on end were formerly so placed that their width was parallel to the short side of the mortar. The holes for the 8 bolts were then bored into the block from above, and at a suitable distance below recesses were chipped out to receive the nuts which held the lower ends of the bolts. Now the planks are so placed that their width is parallel to the long sides of the mortar. The bolts are only threaded at their upper ends, and end in an eye at the bottom, 2 inches bolts pass horizontally through these loops from side to side of the block, the planks on the two sides of the block where the bolts pass down, being cut out to receive them.

In addition to the mortar being more securely and evenly tied to the block, this makes the replacement of a mortar-block if required much easier. The pit need only be dug out in front of the mortar, and when the front binders have been removed it is easy to tear out the planks one after another with pick and adze. In putting in the new block, the two out-

side rows of planks, with places cut to receive the bolts, are kept ready so that only four horizontal 2½ inches holes for the rods need be bored when the planks have been spiked together.

Battery-posts are usually made of 12 by 24 inches timber with recesses cut for the boxes of the cam-shaft. They are set on the short sides of the mortar and are independent of the mortar-block, standing on the cross-sills which rest at right angles across the mud-sills; they are tied together by the upper and lower guide-timbers and at the foot by two beams bolted to them, running parallel with the long side of the mortar-block, and let into the cross-sills.

The frames are braced either from back or front of the battery, depending on the way in which power is transmitted to the cam-shaft. When the line-shafting is at the back they are braced by inclined struts at the back between the posts and cross-sills. When the cam-shafts, however, receive their motion from line-shafting in the cam-floor in front, the posts are braced by horizontal cross-beams, resting on a line of posts in front, and projecting beyond them, which are strutted in the angles, and tied together by a longitudinal cap-piece.

Guides.—The stems work in two sets of guides fixed to the guide-timbers which tie the battery-frames. The upper guides are above the tappets, the lower ones below the cam-shaft. At the Homestake mill the centre of the lower guides is 17½ inches above the top of the mortar; the cam-shaft is 4 feet higher from centre to centre, and the centre of the top guides is 3 feet 10½ inches above this. At the Caledonia mill the distance from the top of the mortar to the centre of the lower guides is 16½ inches, from these to the centre of the cam-shaft is 3 feet 4½ inches and between the cam-shaft and the top of the guides, from centre to centre is 4 feet 2½ inches. Each set of guides is provided with liners (guide-blocks) consisting of two strips of 4 inches pinewood, 16 inches deep, provided with semicircular grooves for the stems. When new, small wooden strips are inserted between the back and front of the blocks to hold them slightly apart, these strips are removed as the grooves become worn, bringing the faces of the guide-blocks nearer together. When still further worn the faces are planed to diminish the depth of the grooves, so that the stems may not be too loosely held. Each set of guide-blocks is secured to the guide-timbers with eight ⅞ inch bolts. The grooves and the guide-blocks are lubricated with a preparation of black lead and linseed oil, mixed warm so as to form a soft paste. Oak guide-blocks last 18 months, pinewood only four.

Mortars.—Two kinds of single-discharge mortars are used in the district, each being a solid casting. The sides and bottom are so thick that a lining is dispensed with, but as the feed-opening is approached the thickness rapidly diminishes. The discharge-side projects somewhat, and the other sides are vertical. The top is closed by two pieces of 2 inches planking which rest on lugs ¾ inch wide, cast on the inside of the box 2 inches below the top. These planks have, as usual, five semicircular recesses cut in them, which, when placed together, form holes for the stamp-stems to pass through. Two smaller holes are also bored in them, for two 1 inch water-supply pipes placed between stamps 1 and 2, and 4 and 5.

The mortars are set close together in pairs, 10 stamps being operated by one cam-shaft, and a passage-way is left between every two pairs of batteries.

The water-supply is furnished by a 3 inches main-pipe in front of the batteries, from which a 2 inches stand-pipe passes upward between each pair of batteries. A 2 inches horizontal pipe is connected with the stand-pipe from which four 1 inch pipes branch off at right angles, two for each mortar. A 1 inch pipe at each passage-way close to the mortar, connected with the 3 inches main-pipe, serves for the attachment of a hose for cleaning the apron-plates and other purposes.

The points of difference between the Homestake and Caledonia mortars lie in the dimensions of the lower part of the box, and the number of the inside amalgamating-plates. The Homestake mill mortar weighs 5,400 lbs., is 54½ inches high, and 54¾ inches long. The feed-opening (6½ inches below the top) is 24 inches long, 4½ inches wide, and 7 inches deep, and continues the same length inside; the incline over which the ore falls being extended to form a lip 4¾ inches wide and 1¼ inches thick, projects into the mortar so as to discharge the ore against the upper half of the stamp-head. The lower edge of this lip is 14 inches above the bottom of the mortar. As it wears out quickly, it is cast thicker in the Caledonia mill mortar.

The discharge-opening in front of the Homestake mortar is 15½ inches from the bottom, 48½ inches long, and 21¾ inches high. The frame-seat is inclined outwards about 10 degrees from the vertical, and there are grooves at its ends to receive the chuck-block, screen-frame, and curtain, which are held in place of keys. The chuck-block is secured also at the bottom by two horizontal keys supported by lugs cast on the lip of the mortar. The bottom flanges are 3 inches high, and 5 inches broad; the bottom is 7½ inches deep, and the sides at the foot of the dies are 3½

inches thick. The width inside at the bottom is 10½ inches,* its length is 50 inches, and height to issue of mortar, *i.e.*, the bottom of the discharge-opening, 8¾ inches. The inside width of the mortar at this point is 13½ inches, and at the top of the discharge-opening it is 20 inches. At the top of the mortar it is 16 inches, and the total inside height is 47 inches. The casting is ¾ inch thick from the top down to the feed-opening on the sides and front, but the back is a little thicker. The life of a mortar is about four years.

The Caledonia mortar weighs 5,700 lbs., is 57½ inches high, and 54 inches long. The feed-opening begins 15½ inches from the top, is 3 inches wide, 11 inches deep, and extends the whole length of the mortar, with a strengthening rib in the middle. Where it enters the mortar it is 50½ inches long, and 7½ inches deep, with a lip 2½ inches thick, and 8 inches wide, measured on the incline. This discharges the ore towards the head of the stamp, and protects the amalgamated plate below. The front discharge-opening (50 inches by 17 inches) is 20 inches above the bottom of the flange, and is inclined forward about 10 degs. The grooves on the sides receiving only the screen-frame and curtain are of simpler construction than the Homestake mortar. The lugs for the horizontal keys are the same. The flange round the bottom is 3 inches thick and 4½ inches wide. The mortar-bed is 7 inches thick and the sides at the foot of the dies are 4½ inches thick. The width inside at the bottom is 10 inches, the length 50½ inches, the height 14 inches to issue of mortar and pulp, where the width is 16 inches and increases to 19 inches at the top of the discharge. The top of the mortar is 13½ inches wide, the total inside height is 50½ inches, and the casting from the top to the feed-opening is ¾ inch thick. A mortar lasts six years, and wears out more at the ends than at the back. The feed-opening, for reasons previously recorded, is longer in the Caledonia than in the Homestake mortar, and its inside lip is thicker and wider in the former type, a difference which is necessitated by the use of the amalgamated plate below. For the same reason the Caledonia mortar is also made wider at the issue. The depth of the discharge-opening of the two types moreover differs. In the Caledonia mortar it is 14 inches, which represents the point of issue of the pulp, whilst in the Homestake mortar it is only 8¾ inches, as the issue is raised 16½ inches above the dies by the insertion of a chuck-block, thus giving the shallower mortar the deeper issue.

Dies.—The dies are cast by the Homestake Company on the spot, using an iron between grey and mottled, the top of the cylindrical column

* Formerly it was 14 inches, but this reduced the crushing capacity.

being chilled. The footplate has bevelled corners, and is 10 inches long, $10\frac{1}{2}$ inches wide, and $1\frac{1}{4}$ inches thick. The column or boss is 9 inches in diameter, and 5 inches high. The level of the die is 10 inches below the discharge, which is over the chuck-block. The die weighs 121 lbs. (one-seventh the weight of the stamp), and lasts about six weeks, crushing 189 tons. By that time the boss has worn down to 2 inches from the footplate, and is slightly convex, its weight being reduced to 30 lbs., it shows a consumption of 48 lbs. of iron per 100 tons stamped.

The Caledonia mill purchases its dies, which are made of chilled white iron. The footplate is 10 inches wide by $9\frac{1}{2}$ inches long, and $1\frac{1}{2}$ inches thick. The boss is 8 inches in diameter and $5\frac{1}{2}$ inches high.

The dies in the Homestake mortar fill the bottom completely, those of the Caledonia only fit perfectly crossways, half an inch of space being left between them. From the bottom of the screen to the top of the die is 6 inches. The die weighs 160 lbs. (about one-fifth the weight of the stamp), and lasts three months, crushing 300 tons of hard rock. The boss is then worn to within 1 inch of the footplate. The worn-out die weighs 38 lbs., making the consumption of iron 40 lbs. for every 100 tons of rock.

Amalgamated copper-plates are placed along the entire length of the mortar. In the Homestake there is one plate only set in the discharge-opening. In the Caledonia a second one is used below the lip of the feed-opening.

In the Homestake mortar the chuck-block, consisting of a 2 inches planking bolted to the back of a $1\frac{3}{4}$ inches board, and extending from 2 to $2\frac{1}{2}$ inches above it, fills the bottom of the discharge-opening, the ends of the plank being held in the end-grooves outside. The inside upper edge of the block is rounded off, and over this and along the inside face a $\frac{3}{16}$ inch copper plate is fastened with iron screws. The recess in front of the chuck-block on the top of the front board ($1\frac{3}{4}$ inches wide and 2 to $2\frac{1}{2}$ inches deep) is taken up by the lower side of the screen-frame, between which and the front board a strip of blanket is laid to form a tight joint. The recess under the chuck-block back of the front board is filled by the side of the opening of the mortar.

The screen-frame is held in place by a vertical plate of iron bolted to the centre of the front board, with a horizontal wedge driven between them. The front board is faced, in the centre of the lower half and ends, with iron-plate to protect the wood against the two vertical and horizontal wedges which hold it to the mortar.

A strip of rubber cloth is tacked to the bottom of the chuck-block, in order to make a tight joint inside between it and the flange of the mortar-

opening. Two chuck-blocks of different heights are used, one 7 inches in height used when the dies are new, and one 5 inches high inserted when they are worn down 2 inches. The height of discharge is thus kept nearly uniform. Wooden chuck-blocks last six months.

Owing to the distance between the edge of the dies and the face of the chuck-block being rather small, viz., 2 inches, it was found in the Homestake mill that the sands driven violently by the water against the copper plate scoured off some of the amalgam. Mr. Graham, the millwright, has therefore replaced the 2 inches planking to which the copper plate is screwed, by a ¼ inch iron plate, to which the $\frac{3}{16}$ inch copper plate is riveted with copper rivets. The face of the 1¾ inches front board being covered with ⅛ inch iron plate, the distance between the dies and the Graham modified chuck-block is 3⅝ inches instead of 2 inches. This iron chuck-block lasts as long as the mortar, and more amalgam collects on it. Of the free gold recovered 55 per cent. is caught on this inside plate.

With wooden chuck-blocks the copper is removed when the block is worn out and reset on a new one, or they are scraped very carefully, put aside, melted, and sold.

The reason why the Caledonia mill has amalgamated plates at both the back and front is that the ore milled is not at all oxidized, making it more difficult to extract the gold. The aim, therefore, is to keep the pulp longer in the battery and present a larger surface of copper plate for amalgamation. The copper plate in front is 5 inches broad, and that at the back 8 inches. Both are made of $\frac{3}{16}$ inch copper plate bolted direct to the inside of the mortar. The lower edge of the plates is 9 inches above the bottom of the dies. Of the free gold recovered 60 per cent. is caught in the box.

Screens.—The Father de Smet mill uses No. 30 brass-wire screens, while all the other Homestake mills employ diagonal slot No. 7 Russian iron of No. 24½ American wire gauge, weighing 0·987 lb. per square foot. The slots are ½ inch long, and there are 8 to the inch. The punched surface is 48 inches by 7 inches, with a 1 inch margin, making the screen 50 inches by 9 inches. A screen lasts two weeks. The wooden frame is 4 feet 4 inches long by 11½ inches deep outside, and has a strengthening piece down the centre. To fasten the screen in place, the lap is first tacked on to hold it in place, then a strip of rubber-cloth 2 inches wide is placed over it. Small holes are punched through the rubber and the lap of the screen, and both are nailed to the wooden frame, the burr facing the inside. The outside of the frame is protected by

three iron facings, ½ inch by 9 inches by $\frac{3}{16}$ inch thick, fastened at the middle and ends with a couple of wood screws. Screens of aluminium bronze have been tried, and found so satisfactory that they are likely to replace Russian iron entirely.

The Caledonia mill uses No. 24 brass-wire screens, the thickness of the wire being No. 26, and the screen-surface, 48 inches by 5⅜ inches. The screen lasts one week. It is fastened to a plain wooden frame, 53 inches by 12½ inches, the horizontal sides being 3½ inches wide, and the vertical sides 2½ inches. Three wooden ribs, 1 inch wide, divide the surface into four panels, and keep it from bulging outwards. The attachments of the screen and frame are the same as at the Homestake mill, except that here it is keyed against the lower edge of the discharge-opening instead of resting on the board of the chuck-block. The Caledonia mill uses wire screens because, though its stamps drop 3 inches farther than the Homestake mill, the splash is not so great, owing to the greater width of the mortar.

The force of the splash in the narrow Homestake mortar is thrown entirely against the screen, while in the wider Caledonia type it is divided between the screen in front and the recess at the back, hence the slot-screen would clog. The upper part of the discharge of both classes of mortar above the screen-frames is closed either by a 1 inch board or a canvas curtain, or by a piece of old belting suspended from a lath. This hangs down and meets the screen inside the mortar. The curtain has the advantage over the board that the amalgamator can easily pass his hand inside, and remove chips of wood liable to choke the screen. In order to break the fall of the pulp (forcibly driven against the screen) on the apron-plate of the Homestake mill, a splashboard is fastened to the frame of the latter, to prevent any amalgam collected there being washed away. The Caledonia mortar has no splashboard, as the pulp does not pass the screen with sufficient force to endanger the amalgam at the head of the apron-plate outside.

Stamps.—The stamps weigh 850 lbs., and have about 16 lbs. to the square inch of crushing surface. The stem of wrought-iron tapers 6 inches at both ends, so that it can be reversed if broken. A stem lasts about three years at the Homestake mill, before new ends have to be welded on; it is 14 feet long, 3⅛ inches in diameter, and weighs 340 lbs. The cast-iron head is 18 inches high, 9 inches in diameter at the top, 8 inches at the bottom, and weighs 240 lbs.; it is not, as is often the case, fortified with wrought-iron rings. The usual keyways for the

removal of stem and shoe are parallel. To fasten on the head to the stem, the latter is let down through the guideholes and the socket of the head is placed beneath it. The stem is then lifted and dropped, and, if necessary, driven on with a sledge-hammer. Then the stem and head are lifted, and dropped several times on to a piece of timber until wedged firmly together. A head lasts five years at the Homestake mill.

The shoes are made of white cast-iron. The cylindrical portion is 8 inches high and 8¼ inches in diameter, with a tapering shank 5 inches high, 4½ inches in diameter at the base, and 3½ inches at the top. They are chilled for 6½ inches from the face, whilst the remaining 1½ inches and the shank are cast in sand and cooled slowly. They weigh 140 lbs.

To fasten the shoe to the head the shank is surrounded by small wooden wedges tied on with string, the shoe is put in position and the head dropped several times on to the dies, which are protected by a piece of planking laid across them.

At the Golden Star mill, instead of tying on the wooden wedges, a strip of canvas is wound round them and tacked to each wedge, forming a sort of collar. This can be slipped over the shank of a new shoe, saving time and labour on clean-up days when shoes are replaced,

After some time a shoe becomes slightly concave, but on the whole wears more evenly than the die.

At the Homestake mill a shoe lasts two months, crushing 270 tons of rock. It is then worn down to 2 inches from the shank and weighs 40 lbs., corresponding to 37 lbs. of iron worn away for every 100 tons of rock crushed.

At the Caledonia mill, a shoe lasts three months and crushes 300 tons. It is replaced when worn down to 1 inch and weighs 35 lbs., corresponding to a consumption of 35 lbs. of iron for every 100 tons of crushed ore.

Tappets.—Gib tappets are used, secured in the Homestake mill with two keys, in the Caledonia with three; they are made of cast-iron, and weigh 130 lbs. The diameter at the ends is 9¼ inches, in the centre (which is 7 inches long) 6 inches. The wearing faces are 2½ inches thick and are reversible: when both become grooved they are planed off in a lathe and replaced. When worn down 1¾ inches (about once in three years) they are replaced by new ones. They rarely split; case-hardened tappets and cams were tried, but the surfaces cracked, and they did not answer well, which has been the writer's own experience elsewhere with steel-faced cams and tappets. Solid steel tappets and cams have not

been tried. It takes between 6 and 8 hours to change the tappets and cams of one battery. The order of drop at the Homestake is 1, 3, 5, 2, 4, at the Caledonia 1, 3, 5, 2, 4, and 1, 4, 2, 5, 3. The Caledonia, crushing harder rock, has a higher drop, 12 inches as compared with 9 inches at the Homestake mill, and consequently has to run more slowly, 74 in place of 85 drops per minute.

Cams and Cam-shafts.—The cams are double and are made of tough cast-iron. The hub, which is on the off-side of the stem, is cast thick enough to stand the strain, but not otherwise strengthened. At the Homestake mill the working-face is 2 inches wide and $3\frac{1}{2}$ inches deep, and at the Caledonia mill $2\frac{1}{2}$ inches wide and 2 inches deep. The hub of both is $3\frac{1}{2}$ inches thick, and the web, which strengthens the cam (commencing deep at the hub, and ending thin at the toe), is $9\frac{1}{2}$ inches deep at the centre in the Homestake pattern and $10\frac{1}{2}$ inches deep in the Caledonia, whilst the distance from the centre of the cam to its point in one case is 17 inches and in the other 19 inches The cams are made of car-wheel iron and last over four years. They are lubricated with axle grease; and to prevent any of this dropping on to the apron-plates, a curtain of canvas is stretched on a frame below them, and catches any grease thrown off while they are in motion.

The cam-shafts are of tough wrought-iron turned in a lathe. They have one key seat. The keys are of steel, and hand-fitted; wrought-iron keys soon loose their shape, while machine-fitted keys get loose very easily. It takes 10 hours to replace a broken cam-shaft, supposing the keys are ready prepared and fitted. As the fitting of each key-seat takes an hour or more, a well appointed mill should have on hand a spare cam-shaft (or more, depending on its size and situation), with the necessary cams and keys ready for use.

The Homestake cam-shafts were formerly made $4\frac{1}{2}$ inches wide and $4\frac{3}{4}$ inches in diameter, and lasted about five years; now they are made stronger, running up to $5\frac{3}{8}$ inches, and have stood ten years. The distance between the centres of the cam-shaft and stem is $5\frac{1}{2}$ inches.

The cam-shaft of the Caledonia is $4\frac{13}{16}$ inches in diameter, and its centre is $6\frac{1}{2}$ inches distant from the centre of the stem.

The cam-shaft pulleys are built up of wood, varying in diameter from 6 feet to $7\frac{1}{2}$ feet. When put in place the shaft is revolved, and the face turned off true.

Crushing Capacity.—The Homestake stamp develops 78,030,000 foot-pounds in 24 hours, crushing 1 ton of ore for every 17,340,000 foot-pounds

developed. The Caledonian stamp develops 90,576,000 foot-pounds in 24 hours, crushing 1 ton of ore for every 27,447,272 foot-pounds. Thus, although the efficiency of the Caledonian stamp is greatest, it crushes less ore. This is accounted for (*a*) by the greater hardness of the rock; (*b*) the greater width of mortar at the discharge (16 inches as compared with 13½ inches); and (*c*) the recess for the plate at the back of the mortar. With a lower discharge a greater crushing capacity would be expected, but the above reasons explain why this is not the case in practice. The smallness of the Caledonian screen (258 as compared with 376 square inches) may be assumed to be counterbalanced by the Caledonia using No. 24 wire against Homestake No. 7 slot (corresponding to No. 30 wire).

Apron-plates, Traps, and Sluice-boxes.—The pulp passing through the screens flows in small waves down the apron-plate, and during the interval between these waves any quicksilver, amalgam, or fine gold passing over the amalgamated surface has a chance of settling and adhering to it. The plate consists of a single sheet of copper, the width of the mortar-discharge, fastened with iron screws to a wooden table. Except at the Deadwood and Golden Terra mills, which have plates 12 feet long, all the other Homestake mills have their apron-plates 10 feet in length, covered with $\frac{3}{16}$ inch copper plate, falling 2 inches to the foot, and discharging into a copper-lined sluice leading to the mercury-trap. The Caledonia apron-plates are 8 feet long, 4 feet 3 inches wide, and the copper plate is $\frac{1}{8}$ inch thick, set at the same grade as the other mills.

The wooden table extends 4 feet beyond the end of the copper plate, narrowing to 4 feet. It has a 1 inch rib down the centre; it is overlaid by two blankets, 5 feet wide and 22 inches long, the upper overlapping the lower one. On these the heavy sands collect; they are washed every half-hour, and they last six months. The pulp from the blankets flows into the mercury-traps, one being placed in the middle of the discharge from each plate.

The plates are of Lake Superior copper, furnished ready for use, and do not require to be annealed; they must be flattened, however, with wooden mallets to make them lie flat and remove any inequalities.

At the Homestake mill they are first scoured with sand-paper, followed by emery cloth, or with tailings rubbed on with a wooden block, 4 inches square, until the face is perfectly bright. If necessary, the sand is moistened with a weak solution of cyanide of potassium, and black spots are often removed with dilute nitric acid. The bright surface of the copper then receives a washing with a strong solution of cyanide of

potassium applied with a soft brush. After two days, the mercury is sprinkled over the plate and rubbed into it with a moist cloth and tailings. When the plate is thoroughly amalgamated it is put in position. More than the usual quantity of mercury is added to the box at first, so that the plate may get into proper condition. This takes from two to four weeks, and to dissolve the copper salts, which stain it during this period, cyanide of potassium or ammonia is added to the battery water.

The mercury-traps save amalgam and mercury not caught on the apron-plates. There are also additional traps at the ends of the sluice-plates outside.

The importance of this simple contrivance is shown by the fact that since their introduction 80 ounces of amalgam and 144 ounces of mercury are recovered at the Homestake 80 stamp-mill monthly, by the inside traps; whilst the outside ones collect 10 to 12 ounces of amalgam and 40 ounces of mercury. They are emptied monthly. At the Caledonia mill the traps are emptied daily (when the plates are dressed) on account of the accumulation of pyrites.

The inside traps at the Homestake mills are wooden boxes, 14 inches long, 17 inches wide, and 24 inches deep, with a copper-lined bottom. They contain three sliding wrought-iron plates, parallel with the short sides of the boxes, set 2½ inches apart. The central partition extends to the bottom, and the two others are 3 inches above it. The pulp flows under the first, over the middle, and under the third.

The outside traps are 48 inches long, 14 inches wide, and 48 inches deep, with three partitions, set 10½ inches apart, reaching from the bottom, to within 1½, 3, and 4 inches below the level of the inlet, the outlet being 6 inches lower. In the middle, between two of the wooden partitions, a sliding wrought-iron plate, ⅜ inch thick, reaches to within 3 inches of the bottom of each box. The Caledonia traps are smaller, as there is one for each apron-plate.

The sluice-boxes, which are below the inside traps, are simple wooden launders, lined on the bottom with copper plates. At the Homestake mill, they are 8 to 10 feet long, 18 inches broad, and have a fall of 1 inch per foot. The copper plate is ⅛ inch thick. At the Caledonia mill they are 8 feet long and 8 inches broad, as less pulp passes through them.

Labour.—All the heads of the different departments are responsible to the superintendent. The mill proper is under an experienced foreman, one foreman being sometimes in charge of several mills.

Next comes the millwright, who in large mills sometimes has an

assistant, called the pipe-fitter. The millwright combines the trades of carpenter and machinist, making and replacing new guides, exchanging cams and cam-shafts, fastening loose cams, replacing screens, making and repairing chuck-blocks, exchanging shoes and dies of crushers, and looking after the water connexions, etc.—in fact looking after all the mechanical work about the mill.

The machinist is in charge of the repair-shop and is generally under the millwright, though at the Caledonia mill the foreman takes this duty; any extensive repairs are made at the Homestake shops.

As the mills are driven by steam, each has two enginemen responsible for their firemen.

There is a night watchman generally for each mill, to guard against fire or other accident.

The man who has the immediate charge of the running of the mill is the head amalgamator. He, like all the other heads of departments, is directly under the foreman, and is in turn responsible for his assistants, amalgamators, crusher-men, oilers, feeders, and labourers. In addition to running the mill he has charge of the collection and keeping of the amalgam, and must therefore be not only capable but trustworthy.

The amalgamators feed quicksilver, regulate the water-supply, and look after the running of the battery in general. Quicksilver is fed every half hour with a wooden spoon like a mustard spoon. The quantity used every 24 hours varies from $\frac{1}{4}$ to $\frac{1}{2}$ lb. for each battery according to the character of the ore.* The correct amount is determined by the feel of the amalgam collected on the plates. If hard and crumbly there is danger of its being carried off by the pulp, and more quicksilver must be added. On the other hand, too much quicksilver makes the outside copper plates too soft and slippery, with the risk of liquid amalgam rolling off, while less amalgam collects on the inner ones.

All the quicksilver is added to the mortar in the Homestake mills, and the amalgam is of medium hardness. At the Caledonia mill the aim is, by adding part to the mortar and the rest to the apron-plates, to make the inside amalgam as hard as may be, and to keep the amalgam on the aprons softer than on those of the Homestake mills.

Each management is satisfied with its own method, and, perhaps, the gold of the Caledonia ore being coarser than the Homestake mill may justify the difference of method.

* Fine gold requires more mercury in amalgamating the same weight of gold, and the loss of mercury is liable to be somewhat increased. Great losses may be occasioned by ores containing heavy sulphides or by over-handling.

The loss of quicksilver at the Homestake mills per year per stamp is 5·27 lbs., or 0·0044 lb. per ton of rock crushed. The loss at the Caledonia mills is 7 lbs. per year per stamp, or 0·0011 lb. per ton of stone crushed.* With the harder and more pyritic ore of the Caledonia mine more mercury is liable to be floured per stamp, but owing to the smaller quantity of rock crushed per stamp, less quicksilver is lost per ton.

The Homestake mills use 1 miner's inch of water per battery, and the Caledonia mill 1¼ inches.

To set the tappets, which is very necessary to maintain the height of drop constant, whether the shoes be new or worn, the stamps are hung up, the mortar opened, the stamps lifted by an iron bar, and a block of wood, 1 inch higher than the desired drop, is placed between shoe and die. The tappet is then loosened, allowed to fall on the prop, and again keyed fast. As the point of the prop (finger), and the blocks used to support the shoe are both 1 inch higher than the required drop, on removing the block, the stamps being each in turn regulated thus, will have the desired uniformity of drop, while the different levels at which the tappets are keyed to the stem, will indicate how much the shoe and die are worn down.

The crusher-men, in addition to tending the grizzlies, breaking the coarse lumps, and feeding the crushers, have to watch for and take out any pieces of wood or iron found in the ore, and throw them aside.

All small pieces of wood finding their way into the mortar are removed by the amalgamators, but very little ought to escape the notice of the crusher-men and ore-feeder men, who should remove any pieces they notice, from the shoots of the automatic feeders.

The oilers have to keep all working parts of the machinery properly lubricated, and should be especially careful to guard against excess of grease about the battery.

The feeders attend to the regular and uniform feeding of the ore; the height of ore between shoe and die should never be more than 1 inch, and as much less as possible without allowing the stamps to pound.

One or two labourers are generally needed to do extra work, which does not fall into the usual routine.

The shifts in the mills are changed monthly.

Only three more men are required in the Golden Star 120 stamp mill, than are employed in the 80 stamp mill of the Homestake works running

* In most cases dealing with free-milling ore, ¼ to ½ oz. per ton of ore milled, or 12 to 15 lbs. per month, is the loss to be expected in, say, a 20 stamp mill.

on the same ore. From this it will be seen that a large number of stamps, whilst greatly increasing production, does not proportionately increase the labour outlay.

Collection of Amalgam, and Dressing the Plates.—The amalgam which has collected on the apron-plates the previous day is removed every morning with the change of night shift. An amalgamator, each with an assistant, has charge of this work. The method at the Golden Star mill will serve to illustrate how this work is done. When the copper plates are to be cleaned the stamps are hung up, the water is turned off, and the splashboard removed, and washed at the head of the apron-plates with a hose. It is then placed at the lower end of the plate, and the hose is turned on the screen and apron to remove any sand collected on them. The copper plate should now be clear and bright, or silver white where the amalgam has collected, though here and there spots may be left on it, which are generally at first a light yellow, but turn darker with exposure to air. The plates may be scraped with a blunt double-edged chisel. Then two men loosen the amalgam with heavy whisk-brushes, beginning at the top and working downwards. When this is done, the amalgam is swept in the opposite direction, and collected at the head of the apron. There it is brushed into an amalgam scoop with a rubber scraper (a sharp-edged piece of belting) and emptied into a small enamelled-iron dish. After this the plates are brightened by brushing them with a whisk-broom, using tailings moistened with dilute cyanide of potassium solution, the men working from the head of the plate downwards. If necessary, a little mercury is sprinkled on to the plate, from a bottle over the neck of which a piece of canvas is stretched and tied. After being cleaned, the plates are smoothed with soft paintbrushes passed transversely over them, beginning at the bottom. This finishes the operation, which lasts 4 hours for 24 plates, or 10 minutes for each battery. The indiscriminate use of acids or alkalies on the plates is strongly to be condemned, as they tend gradually to alter the nature of the copper, and if applied in excess precipitate verdigris in a few days, or form salts of copper, which, becoming gradually converted into oxides, give additional trouble. The whisk-brooms used for brushing are of the ordinary kind, cut short to stiffen them. The brushing should be done in straight lines, commencing at the top, the amalgam being generally brushed back to the top, but sometimes it is removed at the bottom. It should not be brushed towards the centre.

If plates are not run too wet—*i.e.*, with an excess of mercury, the

chances of oxidation are reduced by this method of procedure to a minimum, and a thin coating of amalgam is left over the entire surface, excluding air and preventing verdigris.

The amalgam obtained is contaminated with impurities. To remove these, it is placed in a mortar and diluted with mercury. The amalgamator then adds water, and grinds the amalgam so as to bring all the impurities to the surface. These may be in part washed off (the sands) with a hose, and in part removed with a sponge or wet cloth, which takes up the base-metal amalgam, until the surface of the mercury in the mortar is bright and clear like a mirror. It is then passed through a small strainer, and the residual pasty amalgam is transferred to a piece of linen, and the excess of quicksilver is expressed by wringing. The ball of hard amalgam is locked up in the safe, and kept till the next clean-up. All the sands are returned to the battery, and the quicksilver goes back into stock.

Clean-up.—Twice a month the gold amalgam adhering to the inner copper plates is removed, and any repairs needed about the mill are made. At the Caledonia mill the bi-monthly clean-ups are similar to that at the Homestake mills on the first day of the month. At the last named mills the semi-monthly clean-up is different. On the first day of the month the entire mortar is emptied, and shoes and dies are changed if need be; while on the 15th only the amalgam from the inside plates is removed, and the mercury-traps emptied.

At the Golden Star mill the clean-up on the first day of the month is carried out as follows:—It begins at 7 a.m., the feeding of the battery is stopped a quarter of an hour previously, and the stamps are made to drop slowly, so that at 7 a.m. no more ore may be left in the mortar above the screen-frame. The splashboards are removed, the stamps hung up, the water shut off, and the engine stopped. The mortars on one side of the mill are then opened by removing the curtains, screens, and chuck-blocks. The curtains and screens are first roughly washed by playing the hose over them, and put aside to be more carefully cleaned later. The six chuck-blocks from the batteries on the side of the mill being cleaned, are placed on two apron-plates, at each of which there are four men stationed to remove the amalgam, under the supervision of the head amalgamator. This is done by scraping the copper plates with a chisel when the hard amalgam drops off on to the apron-plate beneath, as much amalgam as possible being removed without exposing the copper; quicksilver is then sprinkled over the plate (to dilute the hard amalgam), then spread evenly over the plate, brightened by scouring with a whisk-broom and tailings,

and finally smoothed with a soft paintbrush. The amalgam that has dropped on to the apron-plate from the three chuck-blocks is collected at the head of the former, and put under lock and key. Thus the chuck-blocks of the entire mill are scraped and cleaned in four sets of six each.

In the meantime, another set of men scrape and wash the rim and flanges of the mortar and collect the amalgam. They also remove the apron-plate amalgam which has accumulated during the previous day. In order to keep the apron-plates soft a little quicksilver is sprinkled over them and evenly distributed with a brush, but they are not dressed till later.

As soon as the amalgam from the apron-plates has been removed, two small platforms are placed across the head of the table, in front of the mortar, for the men to stand on. They then bale out the water still remaining in the bottom, and shovel out the sands above the dies into a heap on the apron-plate (more usually removed in buckets and collected in a tub at the side). These sands are returned to the battery after the dies have been put in place, as they do not contain amalgam. Before the die can be taken out, the stamp has to be raised higher; to do this a block and tackle were formerly used, now a piece of timber is placed crossways on the rests of the splashboard, serving as a fulcrum for an iron bar, with which the head is lifted. It is kept in position by a 4 inches piece of wood on the prop (finger) of the stamp, on which the tappet is let down. The dies are prized up with the bar, lifted out, and roughly cleaned. Those to be exchanged are taken away, and piled up to be carefully scraped and washed in due time. Those that are still fit for use are returned to the mortar, after they have been scrubbed with a scrubbing-brush in a tub.

After the dies have been taken out, the remaining sand is shovelled out and piled in a separate tub to be treated afterwards in the rocker and pan. It is rich in amalgam and contains bits of iron, etc. Any particles of amalgam that may have adhered to the rough sides of the mortar are washed down and added to the sands. The dies are now replaced, new shoes, if required, are put in place on the dies, and the wooden collar slipped over the shank. Then the recesses of the chuck-block, screen-frame, etc., are cleaned in a tub by playing a hose on them, after which they too are put in.

When the chuck-block is in place, and the screens have been scrubbed down with a brush and water, the sands first taken out are shovelled back to fill the bottom of the mortar up to the top of the dies, and the drop of the stamps is next regulated.

If new shoes have to be substituted for old ones, they are fixed on by letting the heads drop on to them, as previously described; the wooden block, 1 inch higher than the drop, is placed across the dies, and each stamp in turn is let down till the head rests on the block, the keys of the tappets are loosened, allowing them to fall on the props, and they are then keyed up again. The screens are then replaced, the apron-plates being dressed in the usual way; any amalgam clinging to the small sluices leading to the traps and to the sluice-boxes is removed, and these are dressed like the apron-plates.

The splashboards are put back in place, some ore is fed into the mortar, the water is turned on, and the stamps of one battery after another are let down from the props, the engine running slowly at first, and, as the last head falls, gradually picking up speed, till the regular beat of the heads reverberates along the line, a sound as familiar as it is inspiriting to dwellers in mining camps.

As the mortars are empty when the mill starts up, care must be taken to regulate the ore-supply accordingly.

In cleaning up a mill all hands have to take part in it, the night shift working 6 hours extra.

This description of the clean-up of a 120 stamp mill shows how it is possible to accomplish in the short space of 7 hours (without outside help) what formerly used to take a day, through the various operations being systematized and worked into one another. When the clean-up of the mill is over and the stamps are once more running, the sands shovelled out from the bottom of the mortars have to be worked up and the amalgam cleaned for retorting.

Two crusher-men are detailed to clean the sands, which are first washed in a rocker. Any coarse bits of iron are picked out and collected in a dish. When the sands have been rocked for sometime, and the hose played on them, the residue remaining in the hopper of the rocker is broken as fine as possible with a wooden mallet. The coarse particles remaining are washed in a coarse screen over the clean-up pan, any amalgam remaining on the screen being picked out and put into the pan. The sands go back to the battery, and the sulphides, etc., which collect on the curtain and riffle of the rocker, are taken out and put into the pan. The settlings in the sluice which conducts the slimes to the waste-flume are shovelled out, and returned to the battery.

To clean the amalgam collected from chuck-blocks, apron-plates, sluices, mortars, shoes, dies, screens, etc., it is charged with water into the clean-up pan (5 feet in diameter, the muller making 30 revolutions

per minute), and from 600 to 700 lbs. of quicksilver is added.* It takes about three hours to clean in the pan all the by-products containing amalgam. When this is all collected and the water above is fairly clear, the muller is raised with block and tackle, and the entire contents of the pan are emptied through the lowest discharge-opening into a square box which overflows into the tailings discharge-box. The muller and the bottom of the pan are well brushed out, with a stream of water flowing in all the time, and the liquid amalgam in the box is drained of water and passed through a strainer. The pasty amalgam is removed and freed of the excess of quicksilver by wringing it in canvas bags under water. The balls of hard amalgam resulting contain about 38 per cent. of gold. The mercury collected below the strainer goes back to the main stock;† that squeezed from the pasty amalgam is first purified by adding some nitric acid, stirring it, and washing with water.

The semi-monthly clean up is much simpler, only the chuck-blocks are taken out and cleaned, replacing dies and shoes if necessary, and cleaning the traps. Their contents go to the pan and are worked with the other products containing amalgam. This clean-up lasts 5 hours.

Once a year the old iron and wood chips collected during the previous 12 months are worked over. The pieces of iron, which are scraped to remove any bits of amalgam adhering to them when they are picked out from the battery-bottoms, are thrown into a heap in the yard, and left to corrode by atmospheric agency. Oxidation is hastened by adding salt to the heap at intervals. The iron at the end of the year having fallen to pieces, is charged with mercury into the pans and its gold extracted. The chips of wood picked out of the mortar are likewise collected in a box, and are once a year burnt in a heap in the yard, and the ashes are collected and amalgamated in the pan. In this way 16 to 18 lbs. of amalgam is saved every year from the two mills of the Homestake Company containing 200 stamps.

Retorting and Melting.—To remove the mercury from the hard amalgam in balls, cylindrical or bulb retorts are used. The cylindrical retort of the Homestake Mill Company is 12 inches in diameter and 3 feet long, holding 1,000 lbs. of amalgam. The usual charge of 500 lbs. is retorted in about 6 hours, using ¼ cord of wood. The retort metal (crude bullion) amounts to 38 or 40 per cent. of the amalgam in the

* Under ordinary circumstances in most mills 200 lbs. is sufficient.

† A large mill of, say, 80 stamps will require about 6 flasks in stock; a 10 stamp mill 3.

charge. At the Caledonia mill it is only 33 per cent.; this no doubt is due to the amalgam being less tightly squeezed. At the Deadwood Terra mill it is often only 25 per cent., and this is accounted for by the fine condition of the gold.

The crude-bullion is melted into bars, using, at the Homestake mill, the 1,500 ounce silver mould (5 inches by 5 inches by 11½ inches), or the 700 ounce mould (3½ inches by 4 inches by 9½ inches). The bars are cast 3 to 4 inches thick, and weigh 1,000 to 1,400 ounces. It takes four hours to melt four 1,400 ounce bars, and the crucible lasts for 8 to 12 charges. The moulds must be warmed and smoked inside before pouring. A little borax or bi-carbonate of soda is invariably added to the melt. If iron be present a little nitrate of potassium is used. Bone-ash is used to thicken the slag and make it skim easily. Phosphorus (in quantities not exceeding half an ounce per melt of 1,800 ounces) may be employed to get rid of the copper, and corrosive sublimate added for bullion containing much lead or antimony.

The loss in melting Homestake bullion is 1·5 per cent., and the average composition of the bars is 820 parts of gold, 165 parts of silver, and 15 parts of base metal. The loss on Caledonia bullion is greater, being 7 per cent., as the amalgam is less carefully cleaned. The average composition of the bullion is: gold, 798 parts; silver, 182 parts; and base metal, 20 parts. The bullion is sampled (chipped or drillings taken), weighed, assayed, and shipped.

Geology of the District.

In the neighbourhood of the Homestake group of mines numerous sheets of porphyry (or more properly speaking felsite) are met with, sometimes cutting across the stratification of the country, but more frequently parallel with it. In the northern half of the belt—the Deadwood Terra and De Smet end—the surface was once overlain by felsite which appears to have been injected between the slates and Potsdam formation of the district, and can still be seen capping the ridges between Gold Run and Bobtail Gulch, and Bobtail Gulch and Deadwood Creek.

Mining.

The cost of operations at the Homestake mine for the year ending June 1st, 1888, was as follows:—Mining, 7s.; milling, 3s. 5½d.; total, 10s. 5½d. per ton; leaving a profit of 4s. 11½d. per ton on 15s. 5½d. ore.

The mining costs were sub-divided as follows:—

	s.	d.
Labour	4	6·50
Dead work	0	11·35
Supplies	0	2·76
Powder	0	0·55
Candles	0	0·84
Machinery	0	2·18
Oil	0	0·64
Timber	0	8·63
Wood	0	2·52
Coal	0	0·21
Total	7	0·18

The cost of mining and milling at the Deadwood Terra mine are stated to be at the present time (1892) 5s. 2½d.* Chlorination-works have of recent years been established in Dakota.

Working Results.

Between June, 1887, and June, 1888, the yield in free gold from the Homestake mines represented 15s. 4d. per ton. Assuming that 85 per cent. of the free gold is saved, the ore would in that case run 18s. 0½d. in value in free gold per ton. Its total value varies from £1 0s. 10d. to £2 1s. 8d. per ton, whilst the amount of concentrates does not exceed 3 per cent. Their value, as shown by experiments, is £5 a ton, the average assay of the tailings is estimated at 6s. 3d. per ton.

Two sets of experiments were made in the spring of 1885 on the Homestake and Golden Star tailings, before and after the introduction of mercury-traps. Before they were introduced 1,124 tons of concentrates (blanketings) had been collected in a separate building (the blanket-house), which assayed £7 6s. 6d. per ton. These, panned down, gave 20·5 per cent. of cleaner concentrates, assaying £8 7s. 5d., and a second grade assaying £3 11s. 2d. per ton. The former yielded by pan amalgamation 56·9 per cent. of their total value.

When, in consequence of these tests the mercury-traps were introduced, the loss was reduced; the concentrates then saved assayed £5 15s. 1½d. per ton, and yielded 92 per cent. of their gold in the pans, but the pyrites still assayed £2 11s. 1d. per ton. The concentration by blankets being too expensive, it was given up.

The tailings from the Highland ore average 4s. 2d. per ton, and from the Deadwood Terra 2s. 1d., seldom running above 3s. 1½d. per ton.

In regard to the fineness to which it is necessary to crush the ore, Dr. Goering made a number of tests to find the relation between size and

* *The Engineering and Mining Journal*, (New York), vol. lv., page 338.

assay value of tailings, samples being taken hourly and the sands obtained dried, weighed, and screened through different sieves. The results were:—

Per Cent. in Weight.		Passing Through Screen.		Remaining on Screen.		Assay Value per Ton.
		No.		No.		s. d.
94·07	...	50	...	—	...	5 2½
2·53	...	50	...	40	...	8 10½
3·40	...	40	...	—	...	11 6

These results show that the loss in the tailings increases rapidly if the screens be allowed to remain too long in use. Another set of experiments on tailings running 8s. 4d. per ton, screened through a No. 30 screen, showed that 6 per cent., which did not pass through the screen, assayed as high as £1 0s. 11d. per ton. The result proved that the heavy Russian iron screens should be changed fortnightly.

The Caledonia mill crushed from May, 1887, to May, 1888, 73,425 tons of stone, yielding bullion equivalent to a return of 16s. 9d. per ton in free gold. The blanket concentrates (amalgamated raw in pans) yielded pure pyrites assaying £18 15s. per ton, and the tailings from the blankets when panned gave concentrates worth £1 9s. 2d. to £1 17s. 6d. per ton.

The cost of milling at the Caledonia, a 60-stamp mill, in 1887-88 was 3s. 7½d. per ton, one-third chargeable to labour and two-thirds to material; a low figure, considering the rock is hard, compared with the Homestake ore.

The two striking features of the Dakota practice are the cheapness, simplicity, and effectiveness of the method by which the free gold is extracted, and the waste of sulphides in the tailings.

Mr. Hofman suggests that in view of the fact that the sulphides would appear to average 3 per cent., worth £5 per ton, they might be advantageously dealt with by passing the pulp through *spitz-lütten* to sort out the coarse sands and mineral, the overflow of the *spitz-lütten* going on to a series of *spitz-kasten*, the outflow of which would be waste. The coarse products drawn from the *spitz-lütten* would contain, according to the experiments made in 1885, free gold, which could be recovered by crushing wet in Chilian mills or rolls, and allowing the pulp to flow over amalgamated plates, and then to pass over a separate series of classifiers (*spitz-kasten*), or go back to the main system. The graded pulp obtained by the different *spitz-kasten* would be separated on round tables into concentrates, middlings, or waste. The middling would be re-worked or pumped back to the main system of *spitz-kasten*.

The cost of concentrating the tailings in this manner would probably

not exceed 4s. 2d. per ton of sulphides. The concentrates could be worked by barrel-chlorination, the total cost of which Mr. Hofman states would probably not exceed £1 13s. 4d. per ton of concentrates. He recommends a combination of two systems of furnaces as likely to cheapen the cost of roasting (where wood costs in this district £1 5s. per cord and labour 12s. 6d. to 14s. 7d. a day). The Spence automatic furnace would do the preliminary roasting cheaply, and the revolving-hearth (the Brunton) would effectually dead roast large quantities of ore, the sulphur of which had been nearly all eliminated. The modern modifications of the latter furnace, such as the Pearce turret or Blake circular hearth, are, the writer believes, specially adapted for dealing with fine ore liable to dust.

The Golden Reward Chlorination Works.

The cost of treating gold ores by barrel-chlorination on a large scale, at the Golden Reward mill, Deadwood, Dakota, has been obtained from careful daily records of the ore treated per 24 hours: these were averaged semi-monthly and monthly, to see where improvements and reductions could be made.* For the months of July, August, September, and part of October, 1891, the amount of ore treated and cost of treatment (including all working expenses, inclusive of interest on capital, taxes, insurance, etc., which always vary with the financial management of works of this character) were as follows:—

1891.	July. Tons.	Aug. Tons.	September. Tons.	First Half of October. Tons.
Amount of ore treated ...	1,430	1,194·75	1,512·75	871
Average amount per day...	46·13	38·54	50·42	54·43
Costs per ton—	s. d.	s. d.	s. d.	s. d.
Milling	6 2½	5 10	6 0	4 11½
Roasting	6 4½	5 7½	5 8½	5 5
Chlorination	7 4	6 11½	6 10½	6 5½
Office salaries	1 8	1 11½	1 6½	1 4
Construction and repairs	1 6	3 10½	0 10½	1 4½
Total cost per ton	23 1	24 3	21 0	19 6½

In the month of August the works were closed down for one week, while building a dust-chamber and flue to the roasting-furnaces, which accounts for the higher cost per ton and lower daily average of ore treated, also for the large item for construction and repairs. It will be seen that the cost of milling is excessive. This was due, principally, to the very

* *The Engineering and Mining Journal* (New York), vol. lv., page 269.

inconvenient arrangement of the mill requiring many more men to handle the ore than would be necessary if the machinery were arranged differently. The roasting was done in Brückner cylinder-furnaces holding 3 tons to a charge; since then, a revolving continuous feed-and-discharge roasting-cylinder, arranged with self-feeding dust-chamber, has been added, which has brought the cost below 4s. 2d. per ton.

The amount of chemicals used in the chlorination and precipitation departments to treat the ore milled in each month, as above, was as follows:—

	July. Consumption		August. Consumption.		September. Consumption.		First Half Oct. Consumption.	
	Total.	Per Ton.	Total.	Per Ton.	Total.	Per Ton.	Total.	Per Ton.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Sulphuric acid ...	37,264	26·82	80,044	25·14	38,083	25·17	21,580	24·77
Chloride of lime ...	15,790	11·04	12,160	10·17	15,840	10·47	8·790	10·09
Crude sulphur ...	542	0·37	881	0·31	479	0·31	253	0·29
Iron sulphide ...	1,106	0·77	952	0·79	1,263	0·82	736	0·84
Costs per ton of ore treated—		s. d.		s. d.		s. d.		s. d.
Sulphuric acid ...	—	1 10¾	—	1 10	—	1 10	—	1 9½
Chloride of lime...	—	1 5¾	—	1 4⅓	—	1 5	—	1 4¾
Crude sulphur ...	—	0 0¾	—	0 0½	—	0 0¾	—	0 0¾
Iron sulphide ...	—	0 2¼	—	0 2	—	0 2	—	0 2⅛
Total cost of chemicals ...	—	3 7½	—	3 5	—	3 5¾	—	3 4¾

Mr. Rothwell considers it possible to treat gold ores, similar to those treated in the Golden Reward mill, for from 8s. 4d. to 10s. 5d. per ton by barrel-chlorination, with a mill constructed on the latest improved plans for economical work, and having a capacity of 125 to 200 tons per day.

In the eastern and southern districts of the United States, where labour, fuel, and supplies cost about one-half of what they do in the western, the cost of treatment ought to be considerably less—with such a plant.

On some exceptional gold ores that do not require roasting, and that are not adapted to free-milling, it is possible for chlorination to compete favourably with amalgamation as usually practised in the stamp-mill, by saving a higher percentage of gold. Thus, in chlorination the fine or float-gold will be saved, and the coarser particles having been brightened by attrition and chemical action (by sluicing the leached pulp over copper plates), the gold in this condition, could be readily amalgamated and saved.

A general outline of the Dakota process has already been given,* but the following additional details, embodying the latest improvements in the method as described by Mr. Rothwell†, will be of interest.

The mill, roaster, chlorination, and power buildings are erected on level ground, and the main ore-bins, larger crusher, and dryer on benches cut in the hill side. The chief objection to the Plattner process, for a plant of 50 tons or more capacity per 24 hours, is its enormous size, and the length of time that it takes to complete a single operation. The problem, therefore, that the engineer has to solve in attempting to treat low-grade ores which will not concentrate is to find a process that will treat his ores in large quantity expeditiously, cheaply, and with as little interruption as possible. It is claimed that these objects are attained by the arrangements in question.

The ore from the mine comes in cars to the top of the main ore-bin, which has a capacity of about 1,000 tons. The ore from the bin goes over a grizzly (with the bars set 1½ inches apart) which delivers the lumps to a rock-breaker that breaks it to 1½ inches size. The product of the breaker, joining the fines which have passed the grizzly, is fed to a revolving dryer, which has a cylindrical shell built of ⅜ inch tank steel, 5 feet in diameter and 18 feet long, set on two heavy cast-iron tyres 4 feet from each end. These tyres rest on adjustable flanged rollers; the roller-frames are bolted to a heavy timber framework, to one end of which is fastened a pivotal casting, while the other end is provided with a set of screw-jacks to permit of the inclination of the cylinder being changed.

The cylinder has usually an inclination of ¾ to 1 inch per foot, and is revolved by spur-gearing round its exterior with an intermediate gearing of cone-pulleys and friction-clutch, which gives a range of speed of ¾ to 2 revolutions per minute. The friction-clutch allows the dryer to be stopped without stopping the mill, and is much simpler than a fast-and-loose pulley and shifting belt. To increase its drying capacity, the cylinder is divided into four longitudinal compartments by double iron-plates ⅜ inch thick, bolted to angle-irons riveted to the shell, and an X iron in the centre of the cylinder. The compartments have a length of 14 feet, which allows 2 feet of free space at each end of the cylinder.

The furnace is built of masonry well strapped with iron, and with ample air-passages around the fireplace, and in the bridge-wall, through which a large volume of air can be passed and heated before entering the cylinder.

* *Trans. Fed. Inst.*, vol. iv., page 249.

† *The Mineral Industry*, 1892, page 233.

The dust-chamber is similar, but not quite so large as that of the roaster, to be described later. From the dryer the ore passes by gravity to the fine crusher (rock-breaker) where it is crushed to pass through $\frac{3}{4}$ inch mesh, and is then raised by a chain-elevator to the first screen. This is doublé, with a coarse mesh within a fine mesh, the object being to protect the latter from undue wear. The screen is hexagonal in form, 9 feet long, 4 feet 6 inches outside diameter at one end, and 5 feet 6 inches diameter at the other. The inner screen is 12 inches less in diameter at each end.

The frame of the screen is a cast-iron hub with six radial arms of 1 inch round iron reduced to $\frac{3}{4}$ inch near the ends. Two of these hubs are keyed on the $\frac{3}{4}$ inch shaft, together with the cast-iron headpiece.

The mesh frames are slid in place in grooved cast-iron pieces fastened to the radial arms of the screen-frame. They are interchangeable, and there are always three spare ones on hand.

The screens make $8\frac{1}{2}$ revolutions per minute. The outside casing is made of double thickness, plain timber inside, and groove and tongue outside, with paper between. The doors, one at each side and one at the end, are hinged to the frame of the casing.

The ore that passes the finer mesh goes to an elevator, and is discharged into the storage-bins; the rejected ore goes through a shoot to a large hopper over the coarse rolls (26 by 15 inches, with heavy steel tyres) which are driven by belts running at 90 revolutions per minute.

The ore from the rolls is elevated to the main sizing-screens, of which there are two of the same construction as the one already described, except that they are only 12 feet long, and are driven with separate bevel gearing and clutch to each screen, so that in case of need one can be stopped, and then the whole quantity of ore passed over the other. The fine crushed ore goes to storage-bins and the coarse to fine crushing-rolls, which are the same size as the coarse ones, and is returned again to the screens.

The rolls are fed by automatic feeders, while an exhaust fan draws off the dust, and discharges it into a collector on the top of the ore-bins. The storage-bins are placed along one side of the mill-building, and have a capacity of about 200 tons of crushed ore. A conveyor carries the ore from the bins to the roasting-cylinder. The latter is 36 feet long, 5 feet in diameter, and built of $\frac{1}{3}$ inch plate. It revolves on five tyres which, like the rollers, spur, pinion, and other gear, correspond with those of the drying cylinder, so that it is only necessary to keep one set of extra parts. The shell is lined throughout with fireclay blocks 6 inches thick, and

moulded to fit the circle. It has projecting shelves the whole length of the cylinder, which raise the ore and shower it through the hot oxidizing gases in the upper part of the cylinder. At the end exposed to the fire, the shell is further protected by a specially shaped block which overlaps the end of the plate, and is held in place by a small piece of square bar iron (fastened to the shell) which fits into a groove in the block. The inclination of the cylinder is 14 inches, and it revolves once per minute.

The dust-chamber, which is arranged to feed the dust back into the roasting-cylinder is hopper-shaped on three sides, the bottom being an inclined cast-iron plate projecting about 8 inches into the upper end of the cylinder. The dust carried out of the cylinder settles in this chamber and, as it accumulates, slides down and mixes with the fresh ore. This arrangement does away with the old auxiliary fireplace and the rehandling of the dust, besides giving the ore to the chlorinators in a much more uniform condition than when the dust is mixed with the ore by hand. From the dust-chamber, the gases pass up an inclined flue on the hillside to a chimney 42 inches in diameter and 60 feet high.

The furnace fireplace is constructed with air-channels and openings through which the temperature and working of the cylinder can be regulated and watched. The fire-arch and bridge-wall are so built that the flame is directed into the lower part of the cylinder, and against the ore as it slides down on the lining. The roasted ore is discharged into a hopper, from which it is drawn into cars and spread on the cooling-floor.

To cool the ore, it is spread out thinly on the floor and furrowed. When the surface has partially cooled water is sprinkled over it, and the whole is raked over again; when sufficiently cool, it is sent to an elevator that discharges into hoppers over the chlorination-barrels. These hoppers are made of No. 14 sheet-iron and have a capacity of between 5 and 6 tons each.

The two chlorination-barrels each have a capacity of 5 tons per charge or 35 to 40 tons per 24 hours. The shells are of tank-steel, ½ inch thick, 9 feet long, and 5 feet in diameter inside, whilst the heads are of cast-iron inserted into the end of the shell and bolted through flange and shell. They are 2½ inches thick and heavily ribbed. The trunnions, which are a part of the head, are 12 inches in diameter and 12 inches long where the bearing comes, and 14 inches in diameter and 4½ inches long inside the bearing, making a total length of 16½ inches; they are bored to fit a 3 inches bolt which passes through them and the entire length of the barrel.

Each barrel has two charging-holes (11 inches by 16 inches) oval in shape. The covers are of cast-iron, and when in place are held down by two heavy yokes and four $1\frac{1}{2}$ inches bolts. An eye-bolt is screwed to the centre of each cover to lift it off, and for this purpose a swinging lever is used which holds it out of the way while the barrel is being charged.

The barrels are lined with lead $\frac{1}{2}$ inch in thickness on the heads, and weighing 24 lbs. per square foot, while the shell and other parts exposed to gas or solution are covered with lead $\frac{3}{8}$ inch in thickness, and weighing 18 lbs. per square foot. The steel shell is made in one sheet with butt joint and cover-plate, and all the rivet heads are countersunk, so that the inside is perfectly smooth. The lead lining is bolted on with flat-headed lead-covered bolts, which prevents any solution getting between the lining and the shell. The barrel is driven with spur-gearing encircling the shell by a pinion and friction-wheel, which can be thrown in to or out of gear, and a brake is also arranged so that the barrel can be stopped at any point in its revolution.

The supporting diaphragm for the filter is placed so that it will assume a horizontal position when the charging-holes are in place for charging. This diaphragm has an area of nearly 30 square feet, being 8 feet 2 inches long by 3 feet 8 inches wide, and is put into the barrel in the following manner :—Two strips of wood, $2\frac{1}{2}$ inches thick on one edge and $1\frac{1}{2}$ inches on the other, 6 inches wide, and the length of the barrel inside, are bolted to the shell through holes left for that purpose. Below these strips is built a lining of wooden staves, $1\frac{1}{2}$ inches thick and 5 inches wide, on which are placed the supporting segments 3 inches thick. One is placed against each head, and five others spaced equidistant between, which brings them nearly 13 inches apart. On the top of the segments the corrugated plates are laid lengthways with the barrel. These plates are of wood, 2 inches thick, four of which in width form the filtering surface. Each plate is corrugated lengthways with grooves $\frac{5}{16}$ inch wide, $\frac{3}{8}$ inch deep, and $\frac{3}{8}$ inch between each groove, while $\frac{3}{8}$ inch holes are bored through the plate 3 inches from either edge, and every 5 inches lengthways cross-grooves are cut to intersect these holes. On the plates is spread the filter and asbestos cloth, woven a little finer than the ordinary gunny sack. Over this is placed an open wood grating of 1 inch by $1\frac{1}{2}$ inches slats, with openings $3\frac{1}{2}$ inches by 9 inches. This grating and the whole filter are held in place by five heavy brace-pieces 3 inches in thickness, the ends of which slip under the wooden strips bolted to the shell; small spacing-pieces are placed between the braces, which prevent their coming out or shifting out of place when the barrel is revolving.

All the woodwork of the interior of the barrel is previously boiled in tar and asphalt until saturated, which prevents it absorbing solution and lengthens its life.

Below the filter at each end of the barrel are the valves through which the solution is drawn to the slime-filters or the storage-tanks.

Above the filter, and between the charging holes and the ends of the shell are the valves and connexions through which the wash-water is pumped for leaching.

On one side of the barrel is placed a large storage-tank built of plank and timber, and lined with sheet lead weighing 6 lbs. per square foot, in the bottom of which is an ordinary quartz filter.

Directly below the solution-valves are the slime-filters which are connected with one another by heavy 2 inches acid-proof hose with special connexions. The slime-filters are cast-iron cylinders, flanged on each end, 30 inches in diameter by 18 inches in length, with cast-iron covers, having inlet and outlet-pipes bolted on. The cylinders are lined with sheet lead weighing 8 lbs. per square foot, and have filters similar to those in the barrel, except that above the asbestos cloth a quantity of quartz sand of different degrees of fineness is spread to a depth of 6 inches; and on the top of this there is a second asbestos cloth, arranged to be lifted out and washed when the fine slime and sand have accumulated to an extent which would retard filtration.

In front of the slime-filters are the precipitating-tanks, two for each barrel. They are placed so that the top of the tank is a little below the outlet of the filter. They are 6 feet 6 inches in diameter by 10 feet 6 inches in height, and made of $\frac{3}{8}$ inch tank-steel, with heavy cast-iron flange and cover on the top end, and at the bottom a $\frac{3}{4}$ inch circular plate is flanged and riveted on the outside of the shell, all rivets being countersunk so as to present a smooth surface for the lead lining to rest upon. A 3 inches bolt passes through the centre of the cover and the bottom and a casting placed as a large washer. The cover has a manhole and three 2 inches holes, from two of which lead-pipes extend nearly to the bottom of the tank. The tank is lined throughout with sheet lead weighing 8 lbs. per square foot. There is a 2 inches hole 9 inches from the centre of the bottom-plate, and another 2 inches hole on the side, just above the top edge of the flange of the bottom-plate. The tanks are supported in position on four heavy iron brackets riveted to the shell about 4 feet above the bottom, which rests on a timber-frame, bringing the bottom of the tank about 4 feet 6 inches above the floor.

Between each set of tanks is placed a filter-press with twelve chambers,

19 inches square and ¾ inch distance-frames. The press has a filtering area of 57 square feet. Two heavy lead pipes from each tank, one from the hole in the bottom and the other from the hole in the side, lead to the press, and each pipe has an acid-proof valve close to the tank.

The generators, in which the gas for precipitating is generated, are placed on the floor at the top of the precipitating-tanks. They are plain cast-iron cylinders, of the same size as the slime-filters. The one for generating the sulphurous acid gas is not lined, but has a cast-iron tray and delagrating-plate. The other for generating the sulphuretted hydrogen gas is composed of two cylinders, one above the other, with a plate having a 3 inches hole in the centre between them. The cover of the upper cylinder has a hand-hole 8 inches in diameter in the centre, and a 2 inches hole near one side. The lower cylinder-cover has a 2½ inches hole in the centre, and a small hole tapped for a 1 inch pipe near the top on one side. Both cylinders and covers are lined inside with lead, and a 2½ inches lead pipe is put in the 3 inches hole in the plate that separates the two cylinders. One end is burnt on to the lead lining on each side of the plate, and the other reaches to within 1½ inches of the bottom of the lower cylinder.

The method of operation is as follows:—The ore from the cooling-floor is elevated to the hoppers over the barrels, and from there is charged into the barrel in which the requisite quantity of water and sulphuric acid for the charge have been put. After the ore, mixed with chloride of lime, has been added, the cover is put on and screwed down tight. The friction-gear is engaged, and the barrel allowed to revolve for 1½ to 2 hours, at the end of which time it is stopped, with the charging-holes so placed that the filter is horizontal. The connexions are then made from the pressure-pump to the barrel with the slime-filter and precipitating-tanks. The pump is started and water forced into the barrel, the pressure being seldom above 40 lbs. per square inch. The first water entering absorbs any free chlorine gas left in the barrel after chlorination, and the gold solution is delivered quite clear into the precipitating-tank. Each precipitating-tank has a capacity equal to the solution from two charges. The storage-tank under the barrels is used in the event of there being more solution than will fill the precipitating-tank, and when the filter-cloth wears out and lets the sand through, the solution that accumulates here is afterwards drawn into the precipitating-tank and the gold precipitated.

After leaching the charge in the barrel, it is emptied into a tank below the slime-filter floor, and thence sluiced to the tailings-dump. The asbestos filter-cloth is washed, so as to free it from any sand that may clog

the interstices of the cloth by directing a stream of water under pressure through a small nozzle against every part of it, the water thus put in is discharged by revolving the barrel, which also washes out any tailings that still remain. The life of a filter-cloth is between 50 and 60 charges.

As soon as the precipitating-tank is full of solution, the sulphurous acid gas generator is started and the gas is forced through one of the pipes leading to the bottom of the tank. The gas is generated from sulphur burnt on a tray in the generator, with a current of air forced in at the bottom and deflected over the surface of the burning mass. The excess of air carries the gas through the pipe into the solution, in which it is rapidly absorbed, the air acting as an agitator. When sufficient gas has been passed into the solution to convert all the free chlorine gas into hydrochloric acid, the sulphuretted hydrogen gas is generated from sulphide of iron and dilute sulphuric acid, the acid solution being poured into the lower cylinder of the generator, upon the sulphide of iron placed on a perforated lead plate close to the bottom of the upper cylinder. Air-pressure is turned into the lower cylinder through the hole in the side, driving the acid solution up through the 2½ inches lead pipe into the upper cylinder, where it comes into contact with the sulphide of iron. The air is also allowed to pass through the generator to the bottom of the precipitating-tank, where it acts as an agitator, and collects the precipitated sulphide in a flocculent form. As soon as the precipitation is complete, the air is shut off and allowed to escape from the lower cylinder, when the acid solution recedes from the sulphide of iron, and the gas ceases to be generated. The acid solution is used over again, until saturated with sulphide of iron.

The precipitate in the tank is allowed to stand for about an hour, in which time most of the sulphide of gold has settled to the bottom. The valve on the pipe leading to the filter-press from the side of the tank is then opened, and the supernatant liquor is allowed to pass through the press, in which any sulphide of gold still in suspension is collected. When filtration becomes slow, air-pressure is turned into the tank and the liquor is forced through the press. After four precipitations the precipitate which has collected in the bottom of the tank is forced into the press, through the pipe in the bottom of the tank. To compress the sulphide-cake in the press, air is allowed to blow through till the filtrate stops coming. The press is then opened, the sulphide-cake is removed, dried, roasted, and put away till the clean-up is made, when the accumulation from 15 days' run is put in a crucible with borax, nitre, and a little quartz sand, fused, and cast in a mould.

The amount of precipitants used to precipitate a tank of 2,500 gallons

of solution is—sulphur, 2 lbs.; sulphide of iron, 4 to 5 lbs.; sulphuric acid, 16 lbs.; and 9 gallons of water.

The capacity of the works is 75 tons per day.

Power for the whole of the works is furnished by a 125 horse-power engine and two 75 horse-power tubular boilers, which are largely in excess of the amount required. A small air-compressor and steam pump take steam from the boilers.

The number of men needed to operate the plant is 30, including the chemist and superintendent.

For power, 6 to 7 cords of wood or 4 tons of bituminous coal are required per day; for roasting, 5 to 6 cords of wood are used per day. The chemicals required are—chloride of lime, 8 lbs. per ton chlorinated, and sulphuric acid, 15 lbs. per ton.

The wear and tear of plant, oil, etc., is estimated at between 1s. 1d. and 1s. 3d. per ton of ore treated.

The buildings to cover the plant are—coarse-crusher and dryer, 34 feet by 38 feet; mill, 38 feet by 40 feet; roaster, 40 feet by 62 feet; chlorination-shed, 36 feet by 54 feet; engine and boiler-house, 46 feet by 40 feet. Space is allowed for one more set of rolls, a second roasting cylinder, and two extra barrels, which would nearly double the capacity of the works.

The Golden Reward mill has paid £12,500 in dividends during the year 1892, and is now treating between 90 and 100 tons per day with 4 barrels at work.

Practice in the Otago District, New Zealand.*

The province of Otago, in the Middle Island, was the first gold-milling district opened in this colony. Its history dates from the famous discovery of auriferous gravel in Gabriel's Gully in June, 1861. Though it has ever since continued to be more of an alluvial field than a quartz-mining camp the last few years have witnessed considerable progress in the development of quartz-reefing, the importance of which is becoming better recognized. For the year ending March 31st, 1892, the yield of gold amounted to 105,531 ounces, worth £423,527. The milling practice bears the impress of the system followed in the older centre of Victoria, but altered conditions have induced certain variations which give it undoubted characteristics of its own.

* The writer is indebted for the particulars given of this and the two following districts to papers by Mr. T. A. Rickard on "Variations in the Milling of Gold-ores." *The Engineering and Mining Journal* (New York), vol. lv., pages 78, 101, 222, 247. 389, 416, 534, and 560.

The three mills, statistics of which are given in the following comparative table, are fairly typical. The Phœnix battery at Skippers is one of the best known in New Zealand, and nestles at the base of the snow-capped range of the Southern Alps. The Premier mill at Macetown is an old one, shortly to be replaced by a larger plant. The Reliance is at Nenthorn, a mining township, which, though of comparatively recent origin, has already passed through many vicissitudes of chequered prosperity.

Name of Mill.	Stamps.				Depth of Discharge.	Capacity of Stamps per Day.	Capacity of Mill per Day.	Grating Used.	Holes per Square Inch.	Concentrates.	Bullion.	Retort.	Wear of Gratings.	Loss of Mercury per Ton of Ore Treated.	Consumption of Water per Minute.
	No. of.	Height of Fall	Weight.	Drops per Minute.											
		Ins.	Lbs.		Ins.	Tons.	Tons.		No.	%	°/1000	%	Days.	Dwts	Gals.
Phœnix ...	30	7½	800	78	3½	1·4	40	Steel cloth	140	Not saved	930	45	6	8·4	4
Premier ...	10	7	750	77	6½	1·2	12		180		949	34	8	7	3½
Reliance	10	7½	850	75	2½	2·0	20		200		850	35	12	5	5

The Phœnix mill, at the head of Shotover river, was one of the pioneers in the utilization of electricity for the transmission of power. The plant was erected in 1884, and consists of two Pelton water-wheels, working under a head of 180 feet, which drive two Brush dynamos, connected by two No. 8 B.W.G. copper wires, forming a line (nearly 3 miles long) to a Victoria motor, which in turn supplies power to run 30 stamps, together with a rock-breaker, and lights the buildings and plant.

Two kinds of grating or screen are used, wire-cloth being chiefly employed, but when the supply runs short the ordinary round punched iron is substituted. The holes in the two cases are of similar size, but the number per square inch is 324 in the one case and only 140 in the other.

The pyrites in the ore has been proved to be of very low grade, and no concentration is therefore attempted.

The loss of mercury was 90 lbs. on a crushing of 3,107 tons of ore. The gold saving is effected by mortar-boxes and blanket-tables, the residues from the one and the washings from the other both undergoing supplementary treatment in an amalgamating-barrel.

The method of milling is extremely simple: the ore passes through a rock-breaker and is fed automatically into the battery, on the principle adopted at Clunes, which has been already described.

The mortar-box has a depth of 9½ inches from the lip to the bottom, divided as follows:—From bottom of grating to top of

thickness of die 4 inches, and false bottom 3 inches. This false bottom consists of two sets of four bars, which are placed under the dies, and are packed in between with sand. Each bar is 3 inches square, and has a length of 2 feet 5 inches. The space between the outer bars and the side of the mortar-box is 3½ inches, the width of the coffer being 15½ inches. The arrangement is an expedient for surmounting the difficulties presented by a mortar, whose shape is unsuited to the nature of the milling required by the ore. Before starting the mill the coarse sand from the previous clean-up is packed between and around the dies.

The order of drop of the stamps is 3, 5, 1, 4, 2. No mercury is added to the ore when in the mortar-box, the gold being caught by the action of gravity alone.

On leaving the mortar-box the pulp has 3 drops, making 18 inches in all, before it reaches the uppermost blanket. This fall serves the purpose of spreading the material. There are no amalgamating-tables, and the pulp passes immediately over the blanket-strakes. These last have a length of 18 feet and a width of 6 feet, subdivided into 4 runs. The gradient is ⅞ inch per foot, and about 4 gallons of water is supplied to each stamp per minute, delivered to each set of 15 stamps (3 batteries) by two 1½ inches pipes under a head of 25 feet.

The blankets are freed of the gold and heavy sand that they collect by vigorous rinsing in a tub of water. The top row of the four runs of blankets is washed every hour, and the lower ones are washed at longer intervals, depending on the richness of the ore.

The blanketings or residues from the washing are removed from the tub when a certain quantity has accumulated, and are conveyed in buckets to a barrel (5 feet by 4 feet), having a capacity of 120 gallons (equal to about 1 ton of blanketings). In running 25 to 30 stamps on average 15 dwts. ore, a sufficient supply for a barrel is obtained each day. The water in the barrel is used cold, and 75 lbs. of mercury is added to it. Experiments are being made with sulphate of copper. The barrel turns at a speed of 20 revolutions per minute. When amalgamation is thought to be completed, usually after 24 hours, the material is emptied into a vat; thence it is slowly fed by a running stream of water to a shaking-table of the Rittinger type, 8 feet in length and 2 feet wide. Below the table there are a few pieces of copper-plate, but these do not serve much purpose. The collection of amalgam from the contents of the barrel by the shaking-table occupies 2½ to 4 hours, depending on the rate of feeding, and this varies with the heaviness of the pulp.

The amalgam, pyrites, heavy sand, etc., thus roughly concentrated are

placed in enamelled iron buckets to be further washed by hand in a pan. This latter has the shape of the ordinary gold pan, but is made of copper, and its surface having been amalgamated by frequent use, it readily collects amalgam.

Mr. Rickard states that on examining the tailings below the shaking-table he found that they contained a large amount of floured quicksilver. The average loss of 8·4 dwts. of mercury per ton of ore is above the ordinary, and is no doubt due to the high speed of running the barrel.

At the monthly clean-up the battery-residues are roughly screened on a riddle, and the larger bits of quartz removed, previous to adding the residue to the blanketings for treatment in the barrel.

The friable character of the mill-stuff makes the wire gratings used preferable to those of punched iron. It is more easily placed in position on the screen-frame, has a much longer time of wear, and much greater area of discharge. The punched iron gives finer crushing at first, before the burr is worn off, but afterwards becomes easily choked up.

The short life of the gratings, a week for the wire, and slightly less for the punched iron, is not due to anything in the ore itself, which is a comparatively clean quartz, but to the fragments of wood (from mine timbers) which to a quite unusual extent find their way into the mill-stuff. They choke up the gratings which, by the pressure of the water and pulp thus held back, are burst. This is notably the case with the punched iron, which discloses lines of weakness along the vertical divisions made by the press employed in its manufacture. The wire cloth, No. 18 mesh, costs 9s. per yard. It is sold in pieces 30 yards long by 2 yards wide. The grating is cut out of this to the size of 2 feet 6 inches by 10 inches. On the other hand, 120 punched Russian iron gratings cost £17 or 2s. 10d. each, as against 2s. 2d. each for the wire cloth. The expenditure under this head amounts to £5 per month for the 30 stamps.

In place of blankets green baize is used, costing 3s. per yard, and has a time of service varying from three to four months. The expenditure per month is equal to £7 for the entire mill. Those least worn are always placed in the first row. The washing is done by boys who receive 7s. 6d. per shift. One stout lad will do the work demanded by three batteries, but cannot manage the washing of the blankets of four batteries, *i.e.*, 20 stamps.

The ore is essentially of the free-milling type, and is broken from a large quartz-lode traversing schists. The quartz often has a laminated or ribbon structure which enables it it to be readily broken. Inclusions (horses) of country rock are common, and the stone only carries ½ to ¾ per cent. of pyrites.

Concentrating tests have shown that the highest grade of concentrates obtained contains only 10 dwts. of gold, giving a value too low for treatment in this locality, and on the small scale required by the circumstances of the case. The gold occurs free. Ore containing more than the usual percentage of pyrites is generally below the average grade,* the gold is not therefore notably associated with the pyrites. It is usually coarse, and often visible. Quartz, which in the stopes does not on examination show occasional specks of gold, is generally of low tenor. On being crushed, the matrix of quartz readily separates from the particles of gold. It might be anticipated that the coarsest gold would be caught in the mortar-box, and that obtained from the first row of blankets would be less fine than that caught on the bottom one, and such is the case. Pieces are found in the battery very coarse indeed, weighing occasionally 5 to 8 dwts.

The mill is lighted by arc lights, and on examining the blanket-strakes by the aid of this powerful light the yellow gleam of the gold particles can be observed scattered over the green baize.

A clean-up shows the distribution of the gold-saving:—230 tons yielded 691 ounces of amalgam, of which 270 ounces came from the blanketings and 421 ounces from the mortar-box residues. On retorting, 313 ounces of bullion resulted, which on melting was reduced to 301 ounces 4 dwts., worth £3 19s. 3d. per ounce.

The most striking features of the milling-practice of the district are that, as a rule, no mercury is used in the mortar, its use being confined to the after treatment, the gold-saving being effected by gravity alone.

It will be allowed that the simpler mill treatment is, the better, because it is usually also cheaper. Another milling axiom is that the treatment should be adapted to the nature of the ore. Here, if the methods employed are elementary, the character of the mill-stuff is no less remarkably simple. Whether the mill succeeds in the extraction of a proper percentage of the value of the gold in the ore is the only question, to be decided. Repeated assays of the tailings from the Phœnix mill prove that excellent work is being done. The composition and character of the ore justify the entire replacement of the ordinary copper plates by blankets, and the successful extraction confirms this method.

In milling, as in mining, one is apt to generalize somewhat hastily, and the good work done by this mill has made the manager an enthusiastic advocate of blankets and an equally pronounced enemy of amalgamating-plates. In an experiment carried out at this mill, two 5 stamp

* In this respect it differs from the ore of many other localities.

batteries were supplied with 80 tons each of the same kind of ore. No. 1 battery was provided with mercury inside the box, with copper amalgamating-tables outside and mercury-wells, and, finally, two rows of blankets; No. 2 battery was supplied with no mercury, and was supplemented by blankets alone. The result of the test showed that 8 ounces (or 2 dwts. per ton) more were obtained by No. 2 than by No. 1 battery.

In condemning copper plates the manager equally objects to the use of mercury in the rest of the mill, and would confine its employment to the final collection of the gold in the blanket-washings. As a case in point, and to confirm the correctness of his ideas, he instanced the Invincible mill on the other side of the same range of mountains where the gold-saving was done by the mercury in the battery itself by wells, amalgamating-tables, and, lastly, by blankets. On ceasing to add mercury to the ore in the mortar-box, it was found that more gold was saved.

The two instances at the Phœnix and Invincible mills merit careful examination. It was scarcely surprising that the addition of mercury to the ore at the Invincible mill, when in the mortar-box, did not improve the gold-saving, nay, that it caused a loss, for the mortar-boxes are merely square iron boxes in no way adapted to the particular work required of them.

The explanation of these abnormal results is to be found in the fact that the mortars were not designed of a shape adapting them to inside amalgamation, and there was no opportunity given to the amalgam to collect out of reach of the falling stamps, but, on the contrary, the quicksilver added was subject to a violent agitation, which caused it to become floured. The particles of mercury thus broken up are readily carried off by the water, and, escaping with the tailings, take with them a certain quantity of gold.

At the Phœnix mill the experiment quoted is vitiated in a similar way, as a mortar-box does not become a successful amalgamating-machine by the mere addition of quicksilver. The batteries of this mill are rectangular in section, with vertical ends and sides, and are in no way adapted to inside amalgamation.

To make a fair comparison between the effectiveness of amalgamation, as against blanket-saving, it is necessary to have the two types of batteries—one roomy and of particular shape, the other narrow and rectangular—kept in view when considering their suitability for the two methods of milling; but there is no suggestion here intended that blankets could be advantageously replaced by copper plates at the Phœnix

mill. Different ores require different modes of treatment, and if blankets will arrest the gold, it is obviously not advisable to use expensive quicksilver or to go to the trouble of copper plates.

The mode of milling at the Phœnix mill is of the utmost simplicity, but it is suited to the ore whose gold contents it is designed to extract.

The Premier mill at Macetown is a much smaller plant, but is engaged in the treatment of a somewhat similar ore by slightly modified methods. The mill possesses 10 heads, weighing 700 lbs. each, and the speed varies from 75 to 80 drops per minute. The height of drop has a maximum of 9 inches and a minimum of 6 inches, according to the hardness of the mill-stuff.

The issue or depth of discharge averages 6½ inches, from 6 inches when the dies are new to 7 inches when worn down. The depth is regulated by the insertion of a blind or blank piece of sheet-iron inside the screen-frame, which increases the issue at the start when fresh dies have been placed in position. As the dies wear down a smaller piece is inserted, and finally the full depth of the screen is utilized. The grating is of round punched iron, 180 holes per square inch. The bullion is 949 fine, and the amalgam yields on retorting 35 to 38 per cent. The gold saving is done by the mortar-box, to which mercury is added, by copper plates on the tables outside, by wells, and finally by blankets supplemented by a berdan pan.

There are no rock-breakers in use, the feeding of the batteries being done by hand. The mortars of the two 5 head batteries are of different patterns. One is more roomy than the other, and therefore discharges the pulp more slowly.

Seeing that amalgamation inside the box is desired, the millman is right in preferring the wider coffer, since it gives more shelter to the particles of gold and mercury. On examination it was found, as might have been expected, that the pulp issuing from the wider mortar was finer than that from the other, although the same kind of screen was used in both.

Contrary to the usual practice, the blankets precede the copper plates; the pulp has a drop of 22 inches to spread it before it falls on to the first row of blankets. These are 12 feet long and 4 feet 3 inches wide, divided by three longitudinal partitions. They slope 1½ inches per foot. The blankets succeed each other in three equal lengths. The first or top row is washed every hour, the second every alternate hour, and the third every third hour. Then follow the copper amalgamating-tables, 9 feet long by 4 feet wide. The total length is subdivided by

five wells, one each at the top and bottom, and three others at equal distances between the plates. Of the five only three are supplied with mercury. They are 3 inches wide and only ½ inch deep.

The residues from the blankets are shovelled from one tub into a second, from which they are fed by a running stream of water into a berdan pan 4 feet in diameter. Instead of the ordinary ball a suspended muller, called the drag, placed at one side of the pan, does the grinding: this modification keeps the grinding and amalgamation separate, thereby preventing unnecessary flouring of the mercury.

A copper plate, 4 feet 8 inches by 2 feet, is placed below the berdan pan with the view of arresting any amalgam escaping in the slimes. At the lower end of the plate there is also a mercury well. The berdan pan makes one revolution for every three drops of a stamp; that is, 25 revolutions per minute, when the average speed of 75 drops per minute is being maintained.

Of the total quantity of amalgam obtained, 60 per cent. is found inside the mortar, 33 per cent. in the blanket-washings, and the copper-tables save the remaining 7 per cent. It was found that by using copper plates below the blankets, instead of a fourth row of blankets, about 5 per cent. more of amalgam was obtained. This is of interest, as proving (what might be inferred) that copper plates are particularly adapted to arresting fine gold, just as blankets are suited to catching it when coarse.

It will be noticed that at none of the mills is there any effort made to concentrate the pyrites. As a rule (the Phœnix ore being a notable exception) the pyrites of the Otago lodes yield a very good grade of concentrates. There is, however, no chlorination or smelting-plant in the province, and any concentrates obtained are shipped to Australia for treatment, at a cost and delay proportionate to the distance. That fact goes far to explain the neglect of this part of the milling.

Both the Phœnix and Premier lodes carry ore, the gold of which is coarse and free; this explains the comparatively crude and very simple method of treatment. Under such favourable conditions blankets are very effectual contrivances for arresting the gold. This system of gold-saving is of very early origin: it was used in America before the discovery of gold in California. The mining districts of the Sierra Nevada borrowed it from the miners of Georgia, and they in turn owed it to those of Verospotak and Nagyag in Hungary. It came back eastward when the discovery of the Gregory diggings started the mining industry of Colorado. It was derived by the millmen of Otago from the mills of Clunes, which, like those of the United States, borrowed it from Europe.

Blankets mark the infancy of milling and belong to the gossan stage of mining; they can only survive those changes in the ore which obtain with increased depth when that ore remains, as rarely happens, unaccompanied by much pyrites, and that pyrites not associated much with the gold.

The Premier mill uses less water than the Phœnix, because the blankets of the latter have less gradient and larger surface. At the Premier mill, mercury is added to the battery-box, while at the Phœnix this is not done. The latter is probably the more correct practice. The gold is coarse and free, and other things being equal, when a large percentage can be arrested by the blankets, it is probable that the still coarser particles which remain inside the battery would be caught there by gravity without using mercury. In both mills the final extraction of the gold from the blanketings is roundabout and clumsy.

In conclusion, while it may appear that the mills of Otago have but little that can be advantageously imitated by those of Colorado or California, because they are adapted to the treatment of an ore of a very simple character, yet the examination of their modes of working may be of value to the millman in causing him to ponder over the why and wherefore of many parts of his own practice, whose advantages he is too ready to accept without always questioning and considering its actual merits.

Practice at Ballarat, Victoria.

In the year 1891, the output of the Ballarat district amounted to 202,704 ounces 1 dwt. 12 grains, of which 127,971 ounces 8 dwts. 9 grains were derived from quartz mining, whilst the remainder was derived from alluvial sources. Dividends amounting to £222,839 15s. were paid during the same period. The quartz yielded on the average at the rate of 8 dwts. 1 grain per ton, while the pyrites (concentrates) contained 2 ounces 3 dwts. 2 grains of gold per ton. The value of the gold ranged from £3 17s. 6d. to £4 3s. per ounce.

The table on the opposite page illustrates the chief features of several of the leading mills.

The Star of the East at Sebastapol is the most productive quartz mine in Victoria, it produced 34,092 ounces of gold, and paid £79,200 in dividends in 1891. The company own two mills, in the newer one the centre stamp drops ½ inch less than the other four, which is said to produce a better splash of the pulp against the grating. The order of drop is 5, 4, 3, 2, 1. When the gold in the ore is found to be unusually

fine the dies are allowed to wear down more than the ordinary maximum of 4 inches, so as to obtain as deep a discharge as possible, the depth at starting being 2 inches.

The gratings carry 200 round punched holes per square inch and last twelve days, but sometimes, when the gold in the ore is very finely divided, gratings with 270 holes per square inch take their place; these wear three to five days.

	Name of Mill.				
	Star of the East (New Mill).	Star of the East (Old Mill).	Britannia United.	New Normanby.	North Cornish.
Stamps—					
Number	60	20	40	20	50
Weight (lbs.)	1,008	784	1,050	784	784
Number of drops per minute	73	75	60	60	72
Height of drop (inches)	8¼	8¼	8	7	8
Average depth of discharge (inches) ...	3	3	1½	4½	1½
Crushing capacity per stamp (tons)	2	1·5	2·1	2	1·8
Crushing capacity of mill (tons)	120	30	84	40	90
Description of grating	Round punched			Russia iron.	
Fineness of grating, holes per square inch	200	150	120	120	160
Percentage of concentrates (per cent.) ...	3½	3½	1	—	2½
	oz. dwts.	oz. dwts.	oz. dwts.		oz. dwts.
Tenor of concentrates per ton	3 9	3 9	1 7	—	5 13
Fineness of bullion (per 1,000)	970	970	978	965	935
Retort percentage	46	46	50	70	85
Wear of gratings (days)	10	12	14	12	6
Consumption of mercury per ton of ore (dwts.)	5·7	5·7	2·6	5·6	9·4
Consumption of water per stamp per minute (gallons)	7½	7½	5	5	2½

As a rule the gold is fairly coarse, there being, however, a marked difference in the product of the two lodes worked in the mine. The amalgam from No. 2 shaft, the ore of which averages 13 dwts. per ton, retorts 45 per cent., while the ore from No. 1, which yields 17 dwts. per ton, retorts 48 per cent., the gold being coarser.

In the new mill, the gold is partly caught in the mortar-box by the introduction of a tablespoonful (4 ounces) of mercury every 2 hours. Outside the tables are covered with plain copper plates, and are given a grade of ½ inch per foot. At their lower end there are two drop wells and one shallow well, which catch but little gold when the plates above them are in good order: they simply serve to arrest any mercury escaping from above. Below are blankets. The blanketings—the residues from the regular washing of the blankets—are stacked, lime is added, and they are allowed to stand two days, after which they are re-introduced into the battery with the usual ore-feed. Below the blanket-strakes are eight

ordinary shaking-tables. The pulp, escaping from these, passes over ties or straight sluices. Three berdan pans are used for grinding the skimmings from the wells.

In the old mill, amalgamation is effected in the mortar, and outside on copper plates, which are given an inclination of $\frac{3}{4}$ inch per foot. They are preceded, however, by two, and followed by three wells. Then come two strips of blanket, 8 feet in length, with a gradient of $1\frac{1}{4}$ inches per foot, succeeded by four shaking-tables, one to each battery. Two berdan pans are used for treating the skimmings: the grinding and amalgamation being commenced with a ball and finished with a drag.

The old mill is stated to be doing the better work of the two, the main distinction between it and the new one being that the copper plates of the latter do that part of the gold-saving which, in the old 20 stamp battery, is accomplished by the upper wells. In both cases most of the gold is caught in the mortar-box by gravity, assisted by the free use of mercury; whilst the larger portion of what escapes the battery is caught by the copper plates in the new mill, and in the old plant by the two wells which precede the plated aprons. The plates involve greater first cost and require more attention than the wells, and it is only in exceptional cases where the ore contains a small proportion of sulphides, and the gold is comparatively free, that wells can compete with plates; but where, as in this instance, they are found to do the work required of them, they are to be preferred for the reasons given.

It is the custom to add a bucketful of lime to each 10 heads every two hours, as this is found to prevent the formation of a black scum on the amalgamating-tables due to the presence of base sulphides in the ore.

At the Britannia United mill, located on Bakery Hill, near the spot where the Welcome nugget (weighing 2,159 ounces and sold for £10,500) was found on June 15th, 1858, the ore treated is more free-milling than that of the Star of the East mine. This is proved by the lower percentage of the concentrates, the greater fineness of the gold, and the increased retort yield. The bullion runs exceptionally high, being worth £4 3s. per ounce, equivalent to 978 fine, and owing to the coarseness of the gold the retort percentage averages 50, while it sometimes reaches 65.

The arrangement of the mill is very similar to that of the new mill of the Star of the East mine. One ounce of mercury is added to the mortar-box per ounce of gold in the ore. Immediately outside the battery there is a well, $1\frac{1}{2}$ inches deep and 3 inches wide, containing 10 lbs. of mercury. The copper plates have a gradient of 1 inch per foot. The blanket-strakes are 16 feet long, divided into three; each strip being 17 inches wide, with

a grade of $1\frac{1}{4}$ inches per foot. Quicklime is added to the battery at the rate of 5 lbs. per 5 heads per 24 hours. The battery water is warmed by conducting the condenser water of the engine into the tank which supplies the mill. This practice of using the condenser water in the battery is decidedly bad, for it is certain to carry grease with it.

At the New Chum Consolidated mill at Bendigo, where condenser water is used in the battery, an examination of the launder which carries it outside the mill showed that the bottom and sides were coated with a slimy ooze which must be prejudicial to amalgamation. At the Britannia United mill, using condenser water, the loss of mercury is only 2·7 dwts. per ton of ore, much less than at the Star of the East mill, where condenser water is not employed. These seemingly contradictory results may be explained by the addition of quicklime, which as an alkali is a solvent of grease, and, though not intended as an antidote for the greasy matter in the condenser water, no doubt acts as such. At the Britannia United mill it is added direct to the ore fed to the battery. At the Star of the East mill it is added only, as before stated, to the blanketings previous to their re-introduction into the coffer. It is in general use at Ballarat for the purpose of neutralizing the acidity of the battery water (produced by the partially decomposed sulphides in the stamper-boxes) and keeps the amalgamating-tables in good order, and prevents corrosion of the screens. The desirability of warming the battery water in a climate like that of Ballarat is, however, open to question.

At the alluvial mines of Otago, New Zealand, the use of mercury is hardly known, the explanation given being that mercury will not act in the cold of that region. This is due to the use of hot water in cleaning-up at both mines and mills. The idea is, of course, erroneous, but there is a substratum of truth in it; for amalgamation is usually assisted by heat, and retarded by cold, but only within narrow limits.

At Black Hawk, Colorado, at an elevation of over 8,000 feet, the millmen say that the bitter cold of winter is better for amalgamation on the copper plates than summer heat, because heat thins the amalgam, and the vibration of the mill, caused by the stamps, tends to make the globules of mercury run off and down the surface of the tables. Cold, on the other hand, thickens the amalgam, and tends to keep it in position; nevertheless, in cases of extreme cold, as in Dakota, the water must be, of course, warmed. Hot water has also one beneficial effect in another way, as slimes which will float in cold water will sink in water which is warmed, owing to the expansion of the air-bubbles, that float the fine dust and create slimes.

On the whole, however, while gold amalgamation is benefited in this way by heat, yet below the temperature of boiling water the effects of a small rise are so slight that it is doubtful if the use of warm water be advisable in ordinary gold stamp-milling. It is certainly not to be recommended in a locality with a summer temperature like that of Ballarat, which is often 75 degs. in the shade, when the water in the mill would in fact be giving off vapour.

The writer believes that in tropical climates an advantage might sometimes be found by cooling the water, say, by storing it in underground tanks.

At the New Normanby mill in East Ballarat the ore treated is of a very free milling nature, the gold which occurs in quartz is almost free from pyrites, and is of a somewhat coarse character, as proved by the retort percentage, the yield of bullion being seldom under 55 per cent., and averaging very nearly 70 per cent.

The North Cornish mill is at Daylesford, in the mining district, but not in the town, of Ballarat. The amalgamation is effected by methods similar to those described as in use at the Star of the East mill. Scarcely 11 per cent. of the amalgam obtained comes from the mortar-boxes, most of it being derived from the skimmings of the wells and the blanket sands. The latter are treated in a set of six berdans, the tailings from which go to a Frue vanner. Up to the end of 1890, on a paid-up capital of only £4,000, the North Cornish property had paid dividends amounting to £85,500, but the mill is stated to be miserably incomplete. Although very favourably situated as regards fall, it is unprovided with rock-breakers or automatic feeders, or with a sufficient number of concentrators (Frue vanners), the ore being one that requires very careful concentration. Fourteen vanners are all that are used, whilst 22 of these machines is the least number that should be employed for good work.

The New Star of the East mill and the Britannia United have exceptionally heavy stamps, following a tendency observable in Californian practice some years ago, which has been abandoned in favour of reversion to a lighter pattern. This is an instance of the needless expenditure of time and money in trying experiments which some other district has already carried out. There is no worse waste than the waste of experience in going over the same ground twice.

In the Britannia United and New Normanby mills the gratings are coarser, and the stamps make fewer drops than the others, owing to the gold being coarser and of a somewhat free character. The unusual coarseness of the gold and the absence of pyrites worth concentration

render rougher stamping permissible, and account for the low drop of the New Normanby as compared with the others.

The North Cornish mill uses the finest gratings, since the gold in the ore it treats is the most associated with pyrites.

In the depth of discharge there is the same wide variation to be remarked as in most colonial mills, a factor the importance of which in milling is too little appreciated all the world over.

In screens the colonial mills have been keeping to the follow-my-leader policy, which is the keynote to all that is deficient in their modes of milling. Actual practical tests show that wire-cloth has a much larger area of discharge than punched sheet-iron. The capacity of many of the Ballarat mills would be increased 10 to 20 per cent. by using wire-cloth gratings, and the small extra cost would be more than compensated by the larger duty of the batteries. The full benefit of wire-cloth screens can be best obtained by having a double set of gratings, so that while one is in use, the other can be dried and cleaned with wire brushes.

The closer work done by the Frue vanners (as compared with ordinary percussion-tables) assists in keeping up the grade of the concentrates at the North Cornish mill, which treats the most refractory ore of any of this group of mills.

The fineness of the bullion tells the same story, that of the Ballarat mills being of unusual purity and finer than the Daylesford bullion.

The very shallow but variable depth of discharge of the North Cornish mortar explains the short life of the screens, which only last, on the average, 6 days.

The top of the dies (when put in new) is flush with the bottom of the screen, and the splash is, in consequence, very violent. The dies are allowed to wear down 6 inches. It is probable that the extraction of the gold would be benefited by leaning towards the greater rather than the lesser depth of discharge, and keeping it uniform.

At the Britannia United mill the average depth of issue is no greater, but it varies between 1 and 2 inches. This, coupled with the fact that the gratings are of coarser mesh, explains why they last more than double as long as at the North Cornish mill.

As the New Normanby and Britannia United ore contains a minimum quantity of sulphides, and the ore is crushed coarser, the consumption of mercury is less than that of the other mills.

The quantity of water used varies with the gradient of the amalgamating-tables, which must be regulated by the heaviness of the pulp ; it is also largely dependent on the extent of blanket surface. The North

Cornish mill uses the least water, since the blankets, being followed by Frue vanners, are shorter than those of the other mills using percussion-tables.

At Ballarat the ample capital and adequate ore-supply remove all excuse for the incompleteness of the mills, so far as concerns appliances and arrangement for the automatic handling of the ore. In the feeding of the 50 stamps of the North Cornish mill, 5 men at 30s. per week are employed per shift, representing a cost of £1,125 per annum. For mining companies like the Star of the East and the North Cornish, both owning magnificent mines, paying large and regular dividends, and possessing very considerable ore-reserves, there can be no excuse for the non-employment of rock-breakers, ore-feeding machines, and a proper and adequate concentrating-plant. They stand as monuments of what should be more truly called obstinate ignorance and perverse disregard of modern experience, than dignified by such a misused word as conservatism. It is greatly to be regretted that for reasons all of them illogical and untenable, the mills of such an important mining district should be so out of date and incomplete. In conclusion, therefore, it must be said that while the actual extraction is excellently carried out, the mills of Ballarat are woefully below the ideal, both in the handling of the ore which immediately precedes stamping, and in the after-treatment which succeeds amalgamation.

Practice in the Ovens District, Victoria.

The Ovens district is north-east of Melbourne, near the border-line dividing Victoria from New South Wales. The mines are scattered over one of the most mountainous parts of Australia, and the mills are located beside streams flowing perennially, in pleasing contrast to the dusty dryness which characterizes most of the mining centres of Queensland, New South Wales, and Victoria. The mills are mostly dependent on custom-work, and are unusally small. The accompanying comparative table, given on the opposite page, indicates their chief features.

The Harrietville mill is the most important and largest in the district, and is the only one that does not do custom-work. It is the property of an English company, who own an extensive group of mines, embracing the Tiddle-Dee-Diddle-Dee, Jackass, Mons Meg, etc. The mortar-box is 5 inches deep, and the dies (which are octagonal) are 4 inches thick. When new the depth of discharge varies from ½ to 1 inch, depending on the amount of sand-packing underneath them. On measuring the depth of discharge in several batteries at the close of a month's work, they were

2¼, 3, 1, 1¼, 1, 2¼, and 1¾ inches, or an average of 1¾ inches. The shoes are 9½ inches in diameter and 9 inches long. A shoe weighs 172 lbs., and a die 84 lbs. Both shoes and dies are of best quality white-iron, fagotted, not cast, costing 16s. per cwt. The shoes wear evenly, but the dies irregularly (cupping). Though the ore is comparatively soft, the average wear of iron per ton of ore crushed is 9·8 ounces of the shoe and 3·4 ounces of the die, the wear of the former being excessive. This is to be attributed to the absence of a rock-breaker, and the use of similar material for both shoe and die. The metal of the die should be less hard and more tough than the shoe, an arrangement which would prolong the life of the latter, and promote more even wear of the surface of the die itself; whilst by breaking the mill-stuff to a more uniform size in a stone-breaker, the shoe would be saved much of the violent abrasion that it otherwise undergoes.

	Name of Mill.				
	Harrietville.	Oriental.	Hillsborough	Railway.	Stephens.
Stamps—					
Number	25	16	8	20	6
Weight (lbs.)	700	784	784	720	840
Number of drops per minute	70	55	60	60	50
Height of drop (inches)	8	9	9½	9	9½
Depth of discharge (inches)	2	3	3	4	4½
Duty per head (tons)...	1½	1⅓	1¾	1⅗	1½
Capacity of mill (tons)	37	20	14	32	9
Description of grating	Rou	nd pu	nched	Russia	iron.
Fineness of grating, in holes per square inch	240	220	200	200	250
Percentage of concentrates	1	†	2	†	†
Gold contents of concentrates (ounces) ...	5	†	1½	†	†
Fineness of bullion (per 1,000)	965	940	940	950	945
Retort percentage	36	52	50	45	48
Wear of gratings (days)	18	17	18	20	18
Loss of mercury per ton of ore (dwts.) ...	19*	8	4	8	8
Consumption of water per stamp per minute (gallons)	5	4	3½	4	4½

For breaking ore in the first instance, a jaw-crusher must necessarily be better adapted to the purpose than a falling weight like a stamp (fine-crushing is not in question), and by compelling the latter to do work which should have been previously done by the former, the material of shoes, dies, screens, and other wearing parts is wasted, the crushing capacity of the mill is diminished, and amalgamation is checked.

The coffer (mortar-box) is of peculiar design, and is provided with an end-discharge. It is 4 feet 6 inches long and 1 foot wide, the interior

* Including pans. † Not saved.

being protected by a cast-iron lining 1 inch thick in four pieces. The bottom of the mortar is flush with the table outside, and it is provided in front with a removable section for cleaning it out.

The grating-frame is in three sections, the two end sections being curved, but each representing a discharge-area corresponding with the one in front, which is 2 feet long. The end gratings have 175 holes per square inch, and the front ones 240. They wear rather longer than those at the end. A set lasts from three weeks to a month, putting through 125 to 200 tons of ore. Complaints in this and other mills are made of the weakening of the gratings along perpendicular lines, caused by the press used in their manufacture. The gratings are not fixed to a frame, but are held in by the latter, which is made of a flat strip of iron bent to the shape of the opening in the mortar-box, and fastened to it by claw-clamps attached to strengthening-ribs, which separate the middle from the side-openings.

The two ends of the mortar-box make a curve, which is an arc, struck from a point in the back of the box. This arrangement of the mortar admits of employing in front, copper tables of unusual width, and by so doing increases the area of amalgamating-surface and the thin distribution of the pulp. An amalgamating table 6 feet wide and 12 feet long is a sight to gladden a millman's heart. The wash of the pulp over the tables is very regular in speed, and even in distribution. The end discharge is generally condemned, and for this reason : that it is ordinarily attempted under the unfavourable conditions of a mortar-box of rectangular shape; the result being that the issue from the end gratings is weak and irregular, whilst the discharge from the front is injuriously affected. These difficulties are overcome at Harrietville by the variation in shape of the mortar-box, and by using screens of larger mesh at the ends than in the front, as the splash against the former is less than in the front of the box.

The gold-saving is done by collection in the mortar-box, by outside tables and mercury-wells, and indirectly by a modified variety of the Rittinger percussion-table: the concentrates collected being first roasted and then ground in pans. Though there are no amalgamating-plates inside the coffer or mortar, mercury is fed into the battery in variable quantities, depending on the richness of the mill stuff. The average amount is about 1 ounce per battery of 5 stamps every half hour.

The amalgamating-tables have a slope of $\frac{7}{8}$ inch per foot, and are subdivided into four sections lengthways. The first, or apron-plate, is 22 inches long, and the one next below is 3 feet long. These are lined with silver-plated copper plates, whilst those below are usually covered with

plain copper plates. A variation in this arrangement, however, enables one to make an interesting comparison of the effectiveness of plain *versus* silver-coated plates.

In front of No. 5 battery the succession is (1) silver-plated copper plates; (2) plain copper plates; and (3) plain copper plates. The middle plate of this set came from the old Mons Meg mill, and was thoroughly amalgamated and in first-class order. In front of No. 4 battery (next to No. 5) the usual order of two silvered copper plates, followed by two plain copper plates, obtained. After a year's work on ore of uniform character it was found that the plain copper plate forming the third plate of No. 5 battery was well amalgamated, while the corresponding copper plate in front of No. 4 was scarcely whitened by amalgam, proving that the second copper plate of No. 5 had not arrested gold and amalgam as successfully as the corresponding silver-plated copper plate, at No. 4 battery.

Following the first copper plate there is a drop-well, 3½ inches deep, succeeded by a shallow ripple, whilst each of the copper plates below is followed by a ripple of similar kind. All are charged with mercury, and cleaned up once a week. Each battery requires 3 bottles of mercury; or 15 bottles is the stock needed by the entire mill. The loss of mercury is about 75 lbs. avoirdupois per 1,100 tons of ore, or 19 dwts. per ton, including the pan-amalgamation of the roasted concentrates. The consumption in actual milling would be about 8 dwts. per ton.

There are five shaking-tables running at 135 strokes per minute, one to each battery.

The ore yields about 1 per cent. of concentrates, chiefly iron pyrites, and the concentrates run 5 ounces of gold per ton, or at the rate of 1 dwt. per ton of crude ore.

The general clean-up on the last day of each month takes 6 hours; the sand collected in the battery being washed over the amalgamating-tables, and thence passed over the shaking-tables. The heaviest portion is returned to the battery on re-starting.

Thirty-three per cent. of the amalgam obtained is collected from the boxes, and of the remaining two-thirds, 8 per cent. comes from the wells, and 58 per cent. from the amalgamating-tables. Of what is saved by the plates fully 90 per cent. is caught in the first length. Of the total yield of gold 86 per cent. is extracted by direct amalgamation, and 7 to 12 per cent. from the concentrates.

The retort yield of bullion varies from 25 to 52 per cent.

The end discharge and clayey nature of the ore explain the large consumption of water.

The framework of the mill consists of light iron standards, and owing to the care taken in building the foundations, the vibration is not excessive. The tappets are keyed on, as it has been proved that the old-fashioned screw-tappet, though very excellent in theory, and answering admirably when first put in, as soon as it becomes at all loose, (which eventually is certain to happen,) is soon worn out and ruined, necessitating frequent stoppages to cut fresh threads.

The mill, with the exception of being unprovided with a rock-breaker, is an excellent one and excellently managed.

The concentrates are roasted in an ordinary reverberatory furnace, with a hearth 27 feet long and 9 feet wide. It is subdivided in its length into three divisions, with a drop between each of 2 inches. The charge is 12 cwts., taking 8 hours to roast, and the daily capacity of the furnace is 4 tons.

The amalgamation-plant, consisting of two Wheeler pans and a settler, is just below and in front of the roaster, and its extraction is exceedingly good, ranging from 90 to 97 per cent. of the gold in the concentrates, as shown by assay.

It seems probable that if the Harrietville mill were equipped with rock-breakers and self-feeders, and a front-discharge mortar with screens of 175 mesh, it would crush more than 1½ tons per 24 hours, with 700 lbs. stamps given an 8 inches drop and 70 drops per minute, or at any rate with slightly heavier stamps falling more rapidly from a less height.

The extreme thinness of the mortar-bottom and excessive weight of the stamp-shoe (172 lbs.) in a 700 lbs. stamp are to be remarked. In America an 850 lbs. stamp usually has a shoe of 125 lbs. The Australian proportion therefore gives an extremely light stem (2½ to 2¾ inches) or tappet, details in which American practice has been controlled entirely by results of experience.

The reason for using finer screens in front than at the sides of the Harrietville mortar is the desire to equalize the volume of discharge. The intention of the end discharge is to cause an even distribution of the pulp over the amalgamating-tables, whose excessive width is thus rendered serviceable. The suggestion has been made, that a copper plate 6 by 8 feet might be better than one 4 by 12 feet, and it seems very sensible. The copper plate should be as wide as, if not slighly wider than, the screen discharge.

As a rule the mortar-opening exceeds 4 feet. If the amalgamating-table is much wider than the discharge, it will be found hard to obtain an even distribution of pulp. The other extreme is, however, more common. Too often plates are less wide than the discharge. In one mill they were

$2\frac{3}{4}$ inches less than the latter, causing a decided eddy along the sides of the table, owing to the pulp being confined to a narrower space than it was discharged from. The increased force of the current thereby caused was certainly prejudicial to the arresting of the gold. In all milling operations the sooner the gold is caught the better, therefore a table which is wide, but over which the pulp is evenly distributed, and which consequently arrests the gold early in its career over the amalgamating-surface, is to be preferred to one less wide but longer, whose gold-saving is continual for a greater distance from the battery. An amalgamating-table is rarely too long; it is poor economy to have it even a little too short. An old copper plate can generally be sold for more than its first cost, and therefore any supposed economy in this direction should be disregarded.

The Combination Process.

The plant and process of treatment which obtains at the re-habilitated mill of the Standard Consolidated Mining Company, of Bodie, California, contains many points which are of great interest, as it differs in some respects from the ordinary, and exhibits another phase of Californian practice, affording us an illustration of the combination process.

The Standard mill contains 20 stamps, and appears to have cost £10,800, or £540 per stamp. Sundry additions were made to the original machinery by the erection of two boilers, 16 feet long and 54 inches in diameter, with brickwork chimney. The mill was originally provided with only one set, necessitating a stoppage of the entire mill for 18 to 24 hours every two months for repairs, which entailed a proportionate loss of product, while expenses ran on as usual. The cost of putting in these boilers was £120, whereas a stoppage of the mill for 20 hours involved a direct loss of £80 to £120; consequently this provision should more than pay for itself in four months. The plant was also increased in 1891 by fitting up two pans and a settler (for the treatment of concentrates), and the addition to the continuous system of two pans and another pointed settling-box.

The ore is crushed wet, and run over silvered copper plates, which, according to the records of the six months prior to the issue of the company's report on January 31st, 1892, took out 80 per cent. of all the free gold and silver contents. The major part of the remainder stays in the batteries, being too coarse and heavy to be thrown out through the screens, and is extracted by amalgamation in the clean-up pan at the end of every month.

The pulp leaving the plates is run over four Frue vanners with belts 6

feet wide, and the tailings from these are led into pointed boxes in order to get rid of the surplus water from the batteries and vanners before treatment in the pans. The thickened pulp discharged from the settling-boxes is raised by means of a bucket elevator to a series of eight pans and three settlers arranged on the Boss continuous system. From the settlers, after passing through an agitator, the tailings escape into the tailing-pits.

The summary of mill work for the year 1891 shows 15,704 tons of ore crushed. The average crushing during the first five months was 1,249 tons, during which time a No. 10 (corresponding to 40 mesh) Russian iron slot-screen was used on the batteries. The average crushing for the last seven months was 1,351 tons, or a gain of 102 tons per month accomplished by the use of a No. 0 (corresponding to 40 mesh) tin punched screen. These latter cost 2s. 10d. each delivered, and two of them will outlast the average Russian iron screen, which costs 13s. 8d.

While battery samples are taken regularly at the mortar-lip, they serve simply as an indication of the grade of the ore, but do not represent its true value, on account of the heavier particles of gold remaining in the mortar, as already explained.

The total value of the ore is obtained by adding the bullion product of copper plates and batteries, the amount of monthly output of concentrates (calculated from daily assays of weighed amounts) and the value in the vanner tailings, this latter item being the product of the number of tons of ore crushed, multiplied by the average tailings assay for the month.

While the percentage of extraction is not high, it is, according to the few available records, from 4 to 5 per cent. greater than that obtained on this ore previous to the present system of milling, and exceeds that of 1890 by 3 per cent.

Analysis shows the ore to contain no base metals other than a very small amount of oxide of iron; nevertheless, it is only partially free-milling, and the percentage of extraction is consequently low.

Richer ore, such as that milled in the spring and summer months, gives higher results on account of carrying a higher proportion of the precious metals in a free state. While, treating a lower-grade ore, as during the last half-year of 1891, the extraction could only be maintained by the partially-successful amalgamation of tailings in the continuous pans. Working on a lower-grade ore a higher extraction was obtained than in previous years, which is certainly satisfactory considering that the ore-treatment is here limited to a certain line of milling operations by the conditions which obtain of high labour, expensive fuel, and costly freights.

The following table shows the expenses for 1891 :—

Month.	Cost per Ton of Ore.			
	Mining.	Milling.	Superintendence, Bullion Freight, Insurance, Taxes, Office Expenses, etc.	Total.
	Dollars.	Dollars.	Dollars.	Dollars.
1891. February ...	6·208	2·982	0·475	*9·665
March	7·665	3·742	0·366	11·773
April	7·784	3·973	0·334	12·191
May	7·840	3·830	0·524	12·194
June	8·149	4·930	0·854	†13·933
July	6·005	4·361	0·876	11·242
August	7·042	3·388	0·564	10·994
September ...	6·727	3·719	0·527	10·973
October	7·770	4·570	0·610	‡12·950
November ...	6·904	3·903	§1·418	‡12·225
December ...	6·842	4·013	0·554	11·309
1892. January ...	6·295	3·370	0·675	10·340
Averages for the year	7·080 29s. 6d.	3·890 16s. $2\frac{1}{2}$d.	0·650 2s. $8\frac{1}{2}$d.	11·620 48s. 5d.

The accompanying statement, showing the cost per ton of mining, milling, and all incidental expenses, exemplifies the expensive conditions alluded to. That milling is being done at a much reduced cost is shown by the fact that 15,704 tons of ore were crushed in 1891, at a total milling expenditure of 61,002·94 dollars, or 3·89 dollars per ton, while in 1889 only 11,498 tons had been crushed at a cost of 60,000 dollars, or over 5·20 dollars per ton.

AMALGAMATION OF 86 TONS OF CONCENTRATES.

86 Tons.	Assay Value per Ton.			Contents based on Assay of each Pan Charge.			Percentage of Extraction	Loss of Mercury per Ton.
	Gold.	Silver.	Total.	Gold.	Silver.	Total.		
	Dols.	Dols.	Dols.	Dollars.	Dollars.	Dollars.	By Assay. Per Cent.	Lbs.
Concentrates ...	67·53	28·18	95·71	5,807·28	2,423·49	8,230·77	$74\frac{8}{10}$	2
Tailings ...	15·34	8·77	24·11	1,318·99	754·70	2,073·69	Actual.	
Assay difference	52·18	19·41	71·59	4,488·29	1,668·79	6,157·08	$78\frac{8}{10}$	
Actual bullion returns	Actually extracted per ton of ore.							
	55·62	19·11	74·73	4,783·56	1,643·39	6,426·95	$78\frac{8}{10}$	
	Actually contained in tailings per ton of ore.							
	11·91	9·07	20·98					

* Cost exceptionally low, in consequence of not including the entire month's expenses, the bullion product being unusually small.

† Cost unusually high, due to payment of all outstanding bills.

‡ Increased, on account of laying in winter supplies for mine and mill.

§ This item higher due to payment of taxes.

The four concentrators produce 10½ tons of concentrates per month, carrying 80 to 100 dollars per ton, *i.e.*, £18 15s. on the average per ton. This represents a contents of concentratable material in the original ore of ⅔ per cent., showing the ore to be hardly of a concentratable character. Nevertheless, the vanners cost so little to operate while furnishing a high-grade product that it pays to continue running them.

There were on hand in July, 86 tons of concentrates, the product of eight months' work. Previously these concentrates had been shipped to the Selby Silver and Lead Company of San Francisco, and on account of heavy freight and reduction costs had yielded to the Standard Company only £9, or 48 per cent. of their value (£18 15s.), this arrangement, therefore, appears to have cost the company £9 15s. per ton.

It being found that the concentrates contained no sulphides and little or no base metal, two pans were fitted up in the mill, and the concentrates were put through a specially adapted slow treatment, with the results shown in the previous statement, and a return of 31 per cent. more than that obtained by shipping to reduction-works.

The tailings from the pans are carefully banked up separately in a reservoir, and will yield a further proportion of their contents after exposure and oxidation.

A Carter magnetic separator, through which the dried concentrates were being passed in order to eliminate the magnetic oxide of iron (of which they contain 5 to 10 per cent.), was discarded, as pan-amalgamation tests showed 16 per cent. higher extraction on the original concentrates than those which had gone through the separator, though the bullion produced was necessarily baser.

The concentrates are now being regularly treated by pan-amalgamation as the best and cheapest method of realizing them quickly.

Chlorination-tests, after roasting with salt and sulphur, have shown no higher percentage of extraction than that of slow amalgamation; moreover, the loss of gold and silver in roasting is considerable (15 to 20 per cent.), and the cost of wood at 10 dollars per cord makes the process more expensive than amalgamation, for which the ore is fitted.

The mercury on the plates and in the pans takes out all the free gold that will amalgamate, the remainder needs a different treatment, and is worked as tailings. For this purpose the mill originally contained six pans and three settlers fitted up for the Boss continuous system, and one pointed settling-box 11 feet by 7 feet by 7¼ feet in size. One or two trial runs had been made previous to 1891, but the product was increased by mixing in some richer material from the blanket-sluices in the Bulwer Standard mill.

The pan capacity being too limited, two pans were added to the above plant in 1891, and another settling-box put in, to take the overflow from the first. Though there is still a loss of slimes in the overflow of the second box, it is impossible to avoid this and retain the proper consistency of pulp in the pans.

It may be here noted that the mill produces an abnormal quantity of slimes, on account of the large quantity of clay accompanying the quartz in the veins. From trial runs of several weeks each it was ascertained that basing the bullion by the use of salt and bluestone in quantity did not increase the extraction, and the needful small amount of chemicals necessary was determined. The tests also showed that much grinding in the pans was to be avoided. Since then the work on the tailings has steadily improved. The average of several chlorination-tests on the raw tailings show about 8 per cent. higher extraction than the continuous-pan system, and for the months of October, November, and December, 1891, and January, 1892, gave a yield of 35 per cent., at a cost of 3s. 8d. per ton.

Most probably, roasting with salt and sulphur, and chlorination by either the Plattner or barrel process, would give a much higher percentage of extraction, but with wood at 10 dollars per cord, labourers' wages at 3·50 dollars per day, and freight rates of 3 and 4 cents. per lb. (the latter has to be taken into consideration on account of chemicals essential to either process), it would be impossible to figure a profit on tailings averaging 7·50 dollars in gold and silver per ton. Large sample lots of tailings were sent to the Denver Gold and Silver Extraction Company (cyanide process) for trial, and to the Noble M. and M. Company, of New York,* in the hope of obtaining a method giving a higher extraction, without roasting or other great expense. The cyanide method after 12 hours' agitation in a ½ of 1 per cent. solution gave only 46 per cent. extraction, which is just 12 per cent. better than the present cheap pan process, a margin that would be more than swallowed up by the greater cost of the process. On 100 lbs. of concentrates sent for trial also, worth 86 dollars per ton, a test of 12 hours' agitation in a 1 per cent. solution gave 88 per cent. extraction, or 9 per cent. in excess of that obtained by pan treatment, a difference which would not cover the cost of the cyanide.

During the year ending January 31st, 1892, 16,336 tons of ore was mined, including 8,658 tons of filling from the old stopes. The total cost of working per ton was:—Mining, 6·14 dollars; ore transport, 0·113

* A 200 lbs. sample of vanner-tailings when treated, gave only an extraction of 38 per cent.

dollar; milling, 3·525 dollars; superintendence, etc., 0·804 dollar; a total of 10·582 dollars. The mill ran 357½ days, crushing 16,336 tons of ore, the average duty of the stamps being 2·42 tons per day. The stamps weigh 750 lbs., have a drop of 6 to 7 inches, and a normal speed of 104 drops per minute. The average value of the ore was 17·93 dollars in gold and 1·99 in silver, or 19·92 in all. The amount saved was 72·8 per cent. Of the free gold 85·5 per cent. was obtained from the apron-plates, and 14·5 per cent. from the battery-sands. There was 123½ tons of concentrates treated, having an average value of 58·97 dollars in gold, and 30·86 dollars in silver, a total of 89·83 dollars per ton. These concentrates yielded by pan-amalgamation 80·6 per cent. The tailings left to weather from the previous year were ploughed over several times, and then amalgamated, 134 tons being put through.

A very base bullion was purposely made, barely 100 fine in gold and silver, but the extraction was very good, averaging 67 per cent., and raising the total extraction on the original concentrates to 93 per cent. The yield of the mill tailings treated in the Boss continuous pans was 67·2 per cent. of their assay value, or an average of 12·47 dollars per ton. The use of acid, in place of salt and bluestone which have proved efficacious, was discontinued as it was found more expensive, and gave no better results.

(To be continued.)

The meeting then closed.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE ODDFELLOWS' HALL, KILMARNOCK, DECEMBER 9TH, 1893.

MR. GEORGE A. MITCHELL, VICE-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected by ballot:—

FEDERATED MEMBERS—

Mr. ALFRED SCOTT THOMSON, Brayton Domain Collieries, Aspatria.
Mr. JOHN ALLISON, 59, Waterloo Street, Glasgow.

The SECRETARY read the following Report of the Committee on the Bearing Surface of Pump-valves:—

REPORT OF THE COMMITTEE ON THE BEARING SURFACE OF PUMP-VALVES.

In May last it was remitted to a committee consisting of Messrs. John Durie, Henry Rowan, and Dugald Baird to further investigate the question of the relation between the bearing surface of a pump-valve and the pressure required to lift it, which was raised in the discussion of Mr. Baird's paper to the Institute on "Pump-valves,"* and to report.

Since that time the members of committee have individually made various experiments and observations, and these when compared and grouped together lead to the conclusion that valve cover does not give rise to the excessive pressures that have been by some attributed to it, and that when designing or making a water-valve it is a good practical plan to give ample cover.

* *Trans. Min. Inst. Scot.*, vol. xiv., page 130.

During the course of the committee's observations three classes of valves were dealt with :—(1) Valves having metal lids resting on metal seats ; (2) valves having vulcanite lids resting on metal seats ; and (3) valves having leather-mounted lids resting on metal seats. Eleven tests were made by the committee. Ten of these tests were made by fixing a hydraulic gauge on the valve-chest below the discharge-valve, and thereafter fixing the same pressure-gauge on the valve-chest above the discharge-valve, and carefully noting the pressures at both places, especially those just as the valves were opening or about to open. Allowance was made for the relative positions of the gauge as regards static pressure, and care was taken to have the engine going at the same speed at both observations.

One of the tests was made by taking a diagram with an hydraulic indicator, but as this was constructed for pressures from 1,000 to 1,500 lbs. per square inch, the test by it was not considered so accurate as the other method. It, however, gave the same result as the other did. Ten of the tests were made on shaft pumps, and one on a dook pump.

It was found that the rise of pressure above the statical pressure took place from three main causes :—(*a*) From the weight of the valve-lids ; (*b*) from the inertia of the water ; and (*c*) from the valve cover. To enable the rise of pressure from the last cause to be brought out clearly, the rise of pressure from the other two causes had to be carefully noted.

In practice the weight of the valve-lid seldom exceeds 1 lb. per square inch of the valve area, and so the rise of pressure from this source, especially where there is a considerable head of water, is a very small percentage of the total pressure exerted. The rise of pressure due to the inertia of the water is, however, much more important, and varies, with the favourable or unfavourable conditions of the pumping arrangements, from 2 to over 50 per cent. above the statical pressure. These unfavourable conditions arise from too suddenly setting the water in the rising main pipes in motion, and are most marked when the area of the rising main pipes is small relatively to that of the ram ; the rate of acceleration of the velocity of the water being thereby greater.

It was necessary to pay close attention to the condition of the valves experimented with, as to whether they were in good tight working order, or whether they were worn, cut, or corded, thereby allowing a free passage of water from the underside of the valve to the top side without the valve-lid lifting.

Of the three classes of valves mentioned, those that were leather-mounted gave the greatest rise of pressure due to cover.

The greatest observed pressure due solely to the valve cover was in the case of a leather-mounted valve, working under a static pressure of 94 lbs. per square inch, due to a vertical column of 219 feet, the cover of the valve being 40 per cent. in excess of the area of the waterway; but the average rise of pressure on leather-mounted valves was found to be only 2½ per cent., while the average valve cover was 37 per cent. But for metal and vulcanite lids there was no observed rise at all due to valve cover.

In the name of the committee,

Dugald Baird, Convener.

DISCUSSION UPON MR. H. AITKEN'S PAPER ON "THE FORMATION OF THE EARTH'S CRUST AND ITS DESTRUCTION."*

Mr. W. S. Gresley wrote that he had perused this paper with considerable interest, chiefly because it was an attempt to supply a rational explanation of the mode of formation of certain stratified rocks or strata, such as are often observed, especially in coal-mining operations, to lie or extend in marvellously uniform thickness and composition over very large areas—such strata or layers apparently calling for some other theory of their deposition than the usual one of sediments transported by rivers, accumulated in deltas or sea-bottoms facing or adjacent to the mouths of the rivers, and ultimately consolidated under pressure and heat into rocks, shales, etc. The physical and stratigraphical aspects of coal-seams and their associated layers of shale, stone clay, etc., had attracted his (Mr. Gresley's) close attention for several years, and the more he studied the component benches or separate divisions of the most uniform and widespread coal-seams (especially those of the coal-field lying westward of the Allegheny mountains in the United States of America) and their accompanying dirt-beds or slate-partings, the less did he feel disposed to attribute the origin of the latter to deposition of river sediments in the same way as delta-deposits are forming to-day. In his opinion it was impossible that the extensive areas over which these wonderfully uniform and persistent slate-partings occur in the same coal-seam with hardly any perceptible changes in thickness, composition, horizon, colour, and fossil contents, could have been so formed, preserved, and sandwiched (between the various accumulations of vegetable matter forming the strata of coal)

* *Trans. Fed. Inst.*, vol. vi., page 210.

by the aqueous deposition of solid particles of rock-materials (detritus of older rocks or strata) at the mouth or mouths of any conceivable river. Observations show that the forms of delta and littoral deposits are more or less lenticular, so that for these thin, flat partings of shale and indurated clay extending over areas of hundreds of square miles (in the Pittsburgh coal-bed, for instance), some other mode of formation seems imperative. That they are segregations (chemically produced) seems improbable, for they never assume nodular shapes. Their composition seems to forbid a chemical precipitative origin. Mr. Aitken's microbe theory might possibly meet the case, nevertheless he (Mr. Gresley) must object to it (at present at all events) for the following reasons:—(*a*) Mr. Aitken takes for granted that the laws of nature operate now as they did in the days of the coal period; therefore, if microbes or selectors were the chief instruments in forming aqueous strata, ought they not to be found doing the same work to-day? Is this the case? (*b*) Mr. Aitken gives us to understand that his researches with microbes prove that they can destroy rocks, but he does not inform us that he has found them building them up, and this is the very process he has to demonstrate before geologists are likely to seriously consider his theory. (*c*) Why does Mr. Aitken give us only the bare idea of his selector mode of rock-formation, when details of the results of his investigations would have enhanced the value of his paper so much, and afforded observers and thinkers something material to work upon instead of leaving them in the dark, firstly, as to what these selectors are, and, secondly, as to how they work, etc.? (*d*) If selectors really made the solid matters of rocks, whence did the waters, in which they worked, derive the elementary mineral matters necessary for rock-building? Sandstone, for instance, is composed of tiny grains of silica mixed with small bits of felspar, calcite, mica, and other minerals, or fragments of crystals, and does Mr. Aitken wish us to understand and believe that each and all of these separate bits of minerals were the excrements or exuviæ, so to speak, of minute organisms? Moreover, were these animalculæ capable of producing just what kind of grains they preferred? or did it take different kinds of selectors to evolve the separate minerals? Then, how about the facets of the quartz and other grains (crystals) so abundantly preserved in many sandstones? (*e*) As to coal-seams and fossils generally: it seems that if microbes could satisfy their appetites with salt or fresh mineral waters, they would hardly be likely to have rejected the apparently more appetizing food of dead shells, fish, plants, and so forth, and so they would annihilate the forms, at least, of all organic remains. (*f*) If microbes were able to produce sand,

grit, etc., why not pebbles and even boulders? Mr. Aitken excepts conglomerates, but omits to say why. Mr. Aitken does not tell us upon what material or where he made his experiments, observations, and tests, but he (Mr. Gresley) should suggest such localities on the sea-margin of the deltas of the rivers Mississippi, Amazon, Po, Nile, Ganges, etc., as being the most likely places to find rock-forming microbes at work, if such still exist. And when we find him suggesting that rearers, edge-measures, and pitching seams were formed as we now have them, viz., highly inclined, he (Mr. Gresley) thought he was certainly entitled to some good reasons for such a notion being advanced in regard to inclined and folded strata. If Mr. Aitken will kindly furnish tangible evidence, based upon sound facts and proper demonstrations regarding what he has found in this connexion, so that geologists may be in a position to apply or reject such evidences on good and sufficient grounds, then, and not until then, can anybody be expected to accept the theory; the generally-accepted explanation of how strata were deposited one above another in water in slowly-sinking areas being, to some minds, inadequate to account for certain layers of shale, etc., notwithstanding. If what he (Mr. Gresley) had said in reference to certain seams of coal being divided horizontally into a number of distinct and separate benches or layers by thin sheets of shale or stone be taken to suppose that he did not believe in the generally-accepted idea that coal-beds, as a rule, represent fossil forests, which grew *in situ* and had their tree-roots in the underclays, it was what he intended. He had for some years past claimed that there was really no evidence in most coal seams, to support the *in situ* growth theory, as usually understood. But possibly the selector theory may yet clear up the mystery surrounding the coal age, though he (for one) did not think it would. He (Mr. Gresley) was now engaged in working out the details of a new (?) theory on the origin of coal-beds—one which seemed to satisfactorily explain all the leading phenomena of these beds—but there would not be anything very revolutionary about it.

The following paper by Dr. Thomson on the "Result of an Experimental Research into Choke-damp Poisoning, with Special Reference to Oxygen as a Restorative," was then read by the Secretary:—

RESULT OF AN EXPERIMENTAL RESEARCH INTO CHOKE-DAMP POISONING, WITH SPECIAL REFERENCE TO OXYGEN AS A RESTORATIVE.

By W. ERNEST THOMSON, M.A., M.D.

During the winter of 1891-92, your Council, through one of its members, approached Prof. McKendrick of Glasgow, to ask his opinion regarding the possible value of oxygen gas as a restorative in cases of suffocation by choke-damp; and his reply was to the effect that he was strongly of opinion that the gas would prove to be useless, and yet was unwilling to make so strong a statement without experimental confirmation. He then, being himself unable to spare the necessary time, most kindly asked the writer to take up the subject with a view to making a thoroughly critical enquiry by experiment. Since, however, such an investigation could not by any means be carried through without considerable expense, Prof. McKendrick applied to the British Association, at the Edinburgh meeting in 1892, for a grant of money, and obtained a sum which if it has not covered the whole of the expenditure, has at least contributed by far the larger part of it.

The committee appointed by the Biological Section of the Association consisted of Prof. McKendrick, Dr. J. T. Bottomley, of Glasgow, and the writer, who carried out the investigation; Prof. McKendrick attended to the expenditure account; and both he and Dr. Bottomley gave valuable hints from time to time.

The whole research, including the essay and the actual record of experiments upon which it was founded, was sent in to the University of Edinburgh as a graduation thesis for the degree of M.D. An abstract has been published in the *Report* of the British Association for the Advancement of Science, and the whole essay will be published in the *Glasgow Medical Journal* for November and December, 1893, and January, 1894. The writer now proposes to give a brief account of that part of it which most concerns the members of the Institute as people interested in mining.

When the writer commenced to study the subject of oxygen inhalation in general, before making any experiments, he was astonished to find what an amount of literature had accumulated about it in the course of years, and

no less astonished to discover that there existed differences of opinion of the widest description between men of high scientific attainments. These differences of opinion proved the undoubted necessity for some further investigation, and upon due reflection it is not so difficult to discover how these conflicting views have arisen.

The main facts of animal respiration are as follows :—Animals require oxygen in order to live, and this oxygen they obtain by respiration. All respiration is not carried on in air, so this description must be understood as applying to animals possessed of air-breathing lungs. This respiration begins and ends in two chemical actions, one of association, the other of dissociation, and between the beginning and the end an immense number of chemical actions take place, whose exact nature is but imperfectly understood. When air is taken into the passages and cells of the lungs part of the oxygen which exists in the air is attracted by an oxygen-seeking substance, hæmoglobin, circulating in the fine blood-vessels in the walls of the lung, and by it is carried away to all parts of the body. As soon as the oxygen combined with the hæmoglobin reaches the smallest branches of the blood-vessels it becomes incorporated with the tissues themselves to form new compounds. This is the chemical association referred to.

When air, on the other hand, is expired from the lungs it is found to contain less oxygen than before, but very considerably more carbonic acid. How has this carbonic acid appeared? After the tissues of the body have been benefited to the full by the oxygen compounds formed by association, the waste products are returned to the blood of the finest veins and eventually pass through the fine vessels disposed in the walls of the lung which are in contact with the air of the outside world. One of these waste products is carbon combined with oxygen to form carbonic acid gas, which has become dissociated from the tissues, carried by the blood-fluid to the heart, and thence to the lungs. Here it acts in the main in accordance with the laws of diffusion of gases, and the tension of carbonic acid in the lung-passages being less than that in the blood-vessels, the carbonic acid diffuses through the thin walls of the latter and escapes into the lung-passages and eventually into the air. Water is another waste product, consisting of hydrogen and oxygen, and is also discharged by way of the lungs. The writer fears this brief and utterly incomplete sketch of respiration may not be quite clear, but it is perhaps sufficient to render his remarks more intelligible.

Physiologists have asserted that the substance hæmoglobin in the blood is only capable of absorbing and carrying away a certain amount of oxygen

and no more. This amount it can obtain from ordinary air, and therefore physiologists have asserted that no matter how great a percentage of oxygen is allowed to pass to the lungs, only that amount will be carried away which is the maximum burden of the hæmoglobin.

But suppose, now, oxygen is compared with air from the physical instead of the physiological point of view. Take an ordinary bell-jar with a stopper at the top and place in it, over water, a mixture consisting of one part of carbonic acid and two parts of oxygen, that is 33·3 per cent. of carbonic acid. Through the opening formed by removing the stopper insert a lighted taper. The flame will burn with increased brilliancy. Now make another mixture consisting of one part of carbonic acid and two parts of air, containing 33·3 per cent. of carbonic acid as before. Introduce the lighted taper, and it will be at once extinguished. No animal could have lived long in either of the jars, yet in the first combustion is increased, and in the second stopped.

The author thinks that the differences of opinion regarding the value of oxygen as a restorative in poisoning by carbonic acid, whether by accident or disease, have in great part arisen through the confounding of the physiological with the physical properties of oxygen, as shown in these simple experiments. Men have said, why, here is oxygen, even when contaminated with carbonic acid to a high percentage, increasing combustion; air will not do this; therefore oxygen must neutralize the carbonic acid, and therefore it must be of use in cases of poisoning by carbonic acid. Thus we have two parties: the physiological, stating what is the case; the other, what ought to be, in their estimation; and in support of the latter class eminent men have tried the gas in various diseases associated with excess of carbonic acid in the blood, and stated that they had found it beneficial. Thus the one side was supported by evidence from the laboratory, the other by observations at the bedside.

The author has diverged from his main path in order to show how authorities have differed on this subject, and how the Council of the Mining Institute of Scotland did well to re-open the whole matter.

It need scarcely be said that such an investigation as this could only be carried out by experiments on animals, and it was not until the commencement of the winter of 1892 that it was possible to begin. Some considerable difficulty was experienced in determining how exactly to go to work to obtain reliable results.

Choke-damp (or what is more usually termed after-damp) consists of a large amount of carbonic acid together with water (in the form of steam) and nitrogen, and is formed by the combustion of fire-damp in a certain

proportion with air. The essentially poisonous element of choke-damp is the carbonic acid, which so alters the relation of the tension of carbonic acid in the air to that in the blood, that the carbonic acid in the latter is prevented from escaping into the air and accumulates in the body; and at the same time occupies so much space in the respirable air that the proper percentage of oxygen (about 20) is lowered. In this way the body is poisoned actively by carbonic acid, and passively by the absence of the proper percentage of oxygen.

It was obvious, therefore, that the animals should be asphyxiated by carbonic acid more or less, according to the requirements of each experiment, and then that oxygen should be compared with air by administering the former in one experiment and the latter in another, and so noting under which of these respirable gases the animal recovered more quickly. But the really difficult point to decide was, whether or not the amount of carbonic acid used for asphyxiating a rabbit, and the amount of respirable gas required to resuscitate it should be measured. For various reasons, into which the author need not enter, the question was decided in the negative, and the physiological condition of the rabbit, as shown by various symptons, together with the time of its immersion in the carbonic acid, were preferred as guides to the degree of asphyxiation; so that, given two rabbits at similar stages of asphyxiation, the times of recovery in different gases (air, oxygen, etc.,) were compared.

For carrying out this plan a special piece of apparatus was made, consisting of a rectangular glass and sheet-iron box with inlet and outlet tubes, and a plate-glass lid fitting with grease to a smooth zinc plate.

The rabbit was placed in this chamber, and the lid having been put on, the gases were admitted from cylinders in which they were stored in a compressed state, and, after passing through the chamber, escaped at the outlet. The carbonic acid was admitted first, and when the animal reached a certain stage of asphyxiation, which varied in different groups of experiments according to a pre-arranged plan, the deleterious gas was turned off and the restoring gas turned on. The author cannot here go into the very numerous details in connexion with this method.

Many experiments were performed, with varied percentages of carbonic acid, varied degrees of asphyxiation, and percentages of oxygen as a restorative which varied from that of atmospheric air (20 per cent.) up to almost pure oxygen (about 96 per cent.).

Before passing on to the consideration of the results arrived at, it may be well to repeat how matters stood before the commencement of the research:—

1. Physiologists have taught that the oxygen in the air is sufficient for bodily requirements, that the blood cannot take up appreciably more than is present in the air, and that under no circumstances is it probable, from previous experiments, that pure oxygen at atmospheric pressure and temperature will avail against asphyxia or disease to a greater degree than air.
2. This investigation is undertaken to verify or else disprove the above propositions. In the latter case, namely, if it be shown that oxygen is a better restorative than air in choke-damp poisoning, the duty of coal-masters is plain. Cylinders of compressed oxygen must become necessary and compulsory articles in every mine.

Unfortunately, the original propositions hold their ground.

The conclusions, then, at which the author has arrived regarding oxygen as a restorative in cases of asphyxia in rabbits, are that, whether asphyxia be slow and chiefly by the accumulation of carbonic acid, or rapid and chiefly by deprivation of oxygen, whether the oxygen be admitted slowly or freely, and even if given pure and assisted by artificial respiration, it is not one whit more rapid in its restoring action than atmospheric air similarly applied.

This is a disheartening conclusion, but there is something more to add to it.

Having noticed how quickly a stream of any respirable gas—air or oxygen—resuscitated an animal asphyxiated by even very large amounts of carbonic acid, the author determined to ascertain how far the mere physical effect of the draught was capable of dispersing the carbonic acid and maintaining life. Here, again, oxygen was compared with air. The experiments performed with this object consisted in subjecting the rabbit to an atmosphere charged with carbonic acid, while at the same time a tube was passed in close to the nostrils, conveying to the region immediately about the head a stream of respirable gas.

The following are the results arrived at:—

1. It is possible to keep an animal for a long time in an atmosphere containing a very high percentage of carbonic acid, provided a gentle stream of a respirable gas be allowed to play on the nares.
2. Oxygen is certainly no better than air for this purpose. This is in striking contrast to its power of keeping a flame burning in a high percentage of carbonic acid, as shewn by the bell-jar experiment.

Although the author has been told by a member that he is too sanguine, and withal not very practical, he again puts forward a suggestion that he has already made in the *Glasgow Medical Journal,* based upon the above conclusions regarding the physical effect of the draught. He is, of course, not a judge of what is or is not feasible in a mine, and he only puts this forward because he considers that the members are entitled to have suggestions regarding things possible of performance placed before them, even although on consideration they may be found to be impracticable.

There is in present use an apparatus which enables a man to pass through an area of choke-damp. It consists of a head-piece similar to that used by divers, and an arrangement for depriving the expired air of carbonic acid, and returning the nitrogen along with a proper proportion of oxygen derived from a cylinder or reservoir. Is it possible, in view of the result arrived at in these experiments shewing the effect of a draught of respirable gas, to simplify the apparatus? Whilst it has been ascertained that a man with this apparatus can pass through an area of choke-damp, and into an area free from it wherein men are imprisoned, although it is obviously impossible for him to bring these men back with him through the poisonous area, will it be possible for him to carry a cylinder of air and a small nose-and-mouth respirator sufficient for a single person, and then by repeating the journey over and over again, allow the imprisoned men one by one to escape?

These are questions better left to the consideration of the practical mining engineer, and they may be worthy of his attention. One thing is certain: there would be no advantage in going to the expense of having oxygen stored under pressure when air might be stored in the same manner and give precisely as good results.

This paper would be incomplete without a reference to an article by Col. Elsdale, which appeared in the *Nineteenth Century*.* and which appears to have attracted the attention of coal-owners. In this magazine article an account is given of the resuscitation by oxygen of a sapper who had been asphyxiated by coal-gas; and it is here assumed that, as the nozzle of the oxygen cylinder was passed into the man's mouth, the gas was administered under pressure; and the conclusion is jumped at that the stomach and lungs must have been filled with oxygen. This seems to be a perfectly unwarrantable assumption, for the gas would naturally force its way out by the short route *viâ* the mouth and nose rather than pass all the way into either the lungs or stomach.

* Vol. xxix., page 719.

Taking his experiments into consideration, the author cannot think the oxygen had anything to do with the rapid recovery in this case. The description, and the suggestions based upon it, contain fallacies which would scarcely be apparent to the unphysiological mind, and by which Col. Elsdale has perhaps been misled. Would a cylinder of air not have done as well? It would, just as well as oxygen, have cleared out the mouth and pharynx of all remains of coal-gas. It would have created a draught on the mucous membrane of the mouth, and so caused some reflex stimulation just as well as oxygen. And if by chance in this case some oxygen passed into the lungs, would not the same amount of air so passed in have done equally well as a restorative, both by clearing out the respiratory passages of coal-gas and by supplying the necessary oxygen, and even supposing the oxygen was of real service in this case, the fact would not necessarily have any bearing upon poisoning by choke-damp.

Seeing that this investigation was primarily undertaken in the interests of the mining community, the author would strongly urge that the experiment be made of keeping a few cylinders of air with nose-and-mouth-pieces ready for use, in those parts of the workings where men might be most easily imprisoned. The expense of the compressed air would be much less than that of oxygen, and the effect would be equally good. It seems quite reasonable to suppose that when a suffocated person has to be dragged through a long passage, itself more or less contaminated as regards its atmosphere, the chances of ultimate recovery will be greater if the effects of this poisonous atmosphere be neutralized at the commencement and during the progress of the work of rescue, than if no such attempt be made until fresh air be reached in the ordinary way.

Any member who may feel an interest in the further question, as to the value of oxygen in certain diseases in which carbonic acid collects in the blood, may peruse that part of the subject above referred to in the *Glasgow Medical Journal* for January, 1894.

Finally, the author would express to the members that he has been much interested in this investigation, in spite of the negative results obtained, although he must confess that the satisfaction would have been greater had the results been positive.

The CHAIRMAN said that he might explain that the matter dealt with in the paper was first brought before the Council by Mr. Thorneycroft, who called the attention of the members to the article in the *Nineteenth*

Century, referred to in the paper. He (the chairman) was commissioned to call on Prof. McKendrick to ask him if it would be possible to make experiments on the subject. Dr. McKendrick stated that from a physiological point of view, he did not consider the use of oxygen would be of much service, but that it would be an interesting subject for experiment. The experiments were then carried out as described in the paper. The results were unfortunately negative, but they were of great interest, and appeared to settle the subject. The Institute was very much indebted to Dr. McKendrick and Dr. Thomson for taking up the matter so heartily, and making such exhaustive experiments.

Mr. THORNEYCROFT said that his attention had been drawn to this subject by Col. Elsdale's article in the *Nineteenth Century*, which described the resuscitation of a man, to all appearance dead, by the use of oxygen at a pressure of 1,200 lbs. to the square inch. Perhaps the shock had more to do with his recovery than the oxygen. However, all the experiments had been conducted under normal pressure, and he believed that oxygen under pressure had greater affinity for organic matter than at normal pressure. Of course the instant the gas escaped from the nozzle it would expand, but how soon it lost its properties he did not know. He regretted the negative result of the experiments so far as they had been carried out.

The CHAIRMAN moved that the thanks of the Institute be accorded to Drs. McKendrick and Thomson for taking up the subject and making the experiments.

The motion was agreed to, and the discussion was adjourned.

Mr. Richard Thomson then read the following paper on "A New Pit Pump":—

A NEW PIT PUMP.

BY RICHARD THOMSON.

The mechanism of this pump is simple and easily got at for repairs. Its working parts are much lighter than those of other pumps. As a consequence better results are obtained from the engine. It is a great convenience also that the pump takes up very little space in the shaft.

Referring to Fig. 1, Plate XIV., it will be seen that as in ordinary force pumps there is a suction-pipe, clack-piece, and ram-casing, with stuffing-box. The ram is made hollow inside, and is turned on the outside. Immediately on the top of the ram is the clack-piece, which moves upwards and downwards with the ram. On the top of the ram clack-piece, steel-tubes are built up to the pit-mouth. The hollow ram and tubes serve the double purpose of pipes and pump-rods. At the pit mouth (Figs. 2 and 3, Plate XIV.) a short steel casting, the inside diameter of which is the same as that of the tubes, is put on, with a stuffing-box on each side, their united areas being equal to the area of the tubes. Into these two short knee-pipes are inserted, one end plain and turned to fit the stuffing-boxes, the other flanged to fit to a Y-pipe. The united lengths of the knee-pipe and Y-pipe are equal to the length of the bell-crank arm. The single end of the Y-pipe rests on a roller under the main centre of the bell-crank. The connexion at the top of the steel casting is a strong, malleable iron blind flange, with short clivis rod and brasses to fit the bell-crank, and secured through the flange with a screw nut and cotter. This Y-pipe discharges the water always at the same level.

The tubes are stiffened in the shaft by means of cast-iron rollers, the grooves of which fit the diameter of the tubes. They are put on in pairs at intervals of 32 feet, beginning at the first tube above the ram.

Spindle-valves are used formed of a conical-edged steel plate let down to the flush of the shell, resting on the edge, feathers and centre, and covered with an indiarubber web, $\frac{7}{8}$ inch thick, which covers the plate and part of the shell. Such is the description of the pump, which may be said to combine the old bucket-lifting pump and force pump in one.

All that can be said in favour of the bucket-lift in sinking may be

affirmed of this pump: and it has other advantages in addition. The chief points in a sinking pump are not only that it be sufficient for the work, but also that it be easily kept in furnishings, easily put into working order, and that it gives little trouble to those in charge. This pump fulfils these conditions. Everything about it is light and easily handled, and it takes up little space in the shaft. In fitting it up for a pit-sinking it is necessary to get the ram and ram-casing 4 feet longer than is required for the length of stroke of the engine, and the suction-pipe extra heavy and conically pointed, so that however rough or uneven the bottom may be, the line of thrust downwards will be through the centre of the ram-casing, clack-piece, and suction-pipe, and any tendency to knee be prevented.

Let us suppose a shaft to be sunk as far as to admit of the above-mentioned pieces being put in place, with two lengths of tubes above the ram-casing, and having the short steel casting with Y-pipe permanently in place, and blind-flange and clivis rod attached to the bell-crank, also a set of rollers on the first tube above the ram, and a set of easy-fitting collaring on the ram-casing about 5 feet below the stuffing-box.

In order to lower the pump as sinking proceeds, it is only necessary to rest the ram at the bottom stroke, cut the joint immediately above the ram clack-piece, signal the engine to the top stroke, fix a 4 feet tube on the top of the ram clack-piece, lower by means of the engine, and fix the other joint. At the next lengthening, the 4 feet length of tube will be taken out and an 8 feet length put in, the process being repeated in lengths of 4 feet until a 16 feet length, which is the usual length of complete tubes, can be put in. These operations may be continued to the depth of 100 fathoms if required, provided the tubes, flanges, bolts, and other fittings are made heavier in proportion to the greater depth.

The pump can go partly on air and get quit of it as easily as the common bucket. It resembles the bucket-pump in this respect, that it lifts one-quarter of the weight of water in the upward movement: and it resembles the ram-pump in the downward movement by having three-quarters of the weight of water to displace. The weight of the tubes assists the engine in the downward movement, and the balance is almost equal at any depth with one bell-crank, which is a great advantage in sinking.

No powerful crane is required to do work about the pump, as the heaviest pieces are the ram and ram-casing, all other pieces being light.

A pump of this description is at work at No. 9 Pit, Wilsontown colliery, and the following are the dimensions and weights of the parts forming it.

The pit is 240 feet deep. The ram is 19 inches in diameter, the cylinder of engine is 28⅝ inches in diameter, and 5 feet stroke, and steam is used at a pressure of 47 lbs. per square inch. The weight of the various parts are:—

	T.	C.	Q.	Lbs.
Top or connecting piece	0	2	2	0
Short steel casting for Y-pipe	0	3	2	0
234 feet steel tubes, 9½ inches in diameter and ¼ inch thick	2	16	0	0
28 steel flanges	0	12	1	14
Bolts, 1⅛ inches	0	4	2	14
Ram and ram clack-piece in one casting...	1	15	0	0
Water in 240 feet of 9½ inches tubes ...	3	7	2	0
The total weight to be lifted, with engine acting direct is...	9	1	2	0

In the downward movement:—

	C.	Q.	Lbs.	T.	C.	Q.	Lbs.
Weight of water	3	7	2	5	14	0	0
Steam power applied				9	1	2	0
The total weight is				14	15	2	0

It requires a column of water 240 feet in height by 22½ inches in diameter to balance this total downward movement, which shows that the 19 inches ram is too small to balance the engine. A back balance weighing about 4½ tons was put on, and since then the engine has worked steadily with steam at a pressure of 35 lbs. per square inch. Before the balance was put on it took steam at a pressure of 47 lbs. per square inch to lift the tubes, and half the steam had to be cut off in the downward movement. This showed that the engine could work a ram 22½ inches in diameter, with steam at a pressure of 47 lbs. per square inch and be equally balanced, the extra size of ram adding very little to the weight to be lifted.

This pump should be very serviceable for dook-workings, and would occupy little room. An arrangement of rollers at every second pipe, similar to that in the shaft above referred to, would be required to keep the tubes stiff in the downward movement. It might be wrought 2,000 or 2,500 feet from the pit-bottom by means of a bell-crank at the pit-bottom attached to the shaft pump-rods and set at any angle. To take it off at right angles, a bell-crank should be set horizontally, made with the arms at right angles from the main centre, the hypothenusal part being hollow as a pipe with stuffing-boxes at each end. Two short knee-pipes are fitted to the stuffing-boxes and attached to Y-pipes, which are in turn attached to the tubes

LEVATION

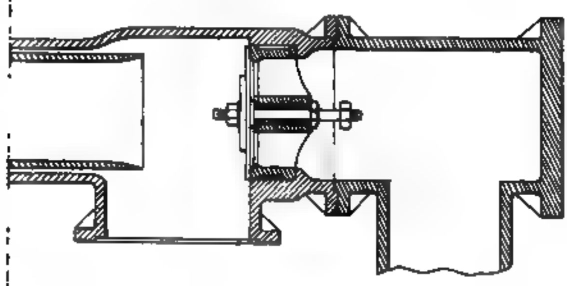


Fig 4. Sectional Elevation.

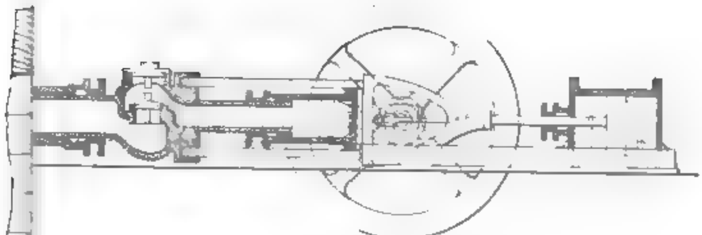


Fig. 5. Plan

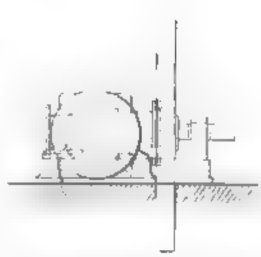


Fig 6 End View

at both ends through which the power is transmitted and the water conveyed. These bell-cranks can be made to fit from a right angle to almost a straight line. In slight curves the tubes can be guided with side rollers set more closely together than is required on the straight. The pump is similar to that for shaft use, except that it has snugs for fixing it to a strong wheeled carriage. The suction-pipe end rests against the mine face with a branch turned downward to the pavement. It is let down as the work proceeds in cut lengths, in a similar fashion to that already described in shaft sinking. Hinged clacks are used instead of spindle clacks and are covered with rubber web.

Figs. 4, 5, and 6, Plate XIV., show a special pump of very simple construction with hollow rams. It has a sole-plate, on which are placed the two ram-casings, crank-shaft, fly-wheel and cylinder working direct on the rams. The crank revolves inside the part which connects the piston to the rams, and may be worked either by steam direct or by a clip-pulley on the crank-shaft driven by wire-rope. The two rams and discharge-clack seat are made in one casting, and carry the valve backwards and forwards as they move in their stuffing-boxes. The receiving end of the ram is double the area of the discharge end, and in the receiving end of the ram-casing a valve is placed, as in other pumps, to check the water that finds its way past it. The small end of the ram determines the size of the pump. The quantity of water that will be discharged in its backward and forward movements keeps up a continuous flow equal to the diameter of the small end of the ram.

The following "Notes on Blasting in Coal-mines," by Mr. H. Bigg-Wither, were taken as read:—

NOTES ON BLASTING IN COAL-MINES.

BY [illegible]

[illegible] made of recent years in scientific inventions [illegible] the safer working of all branches [illegible] has found expression in various [illegible] superfluous to mention in this [illegible] blasting in coal-mines.

[illegible] which some pits are now worked the [illegible] most modern appliances, such as [illegible] explosives, or contrivances for [illegible] minimise these risks. [illegible] than the danger of explosions arose [illegible] years some mining engineers have [illegible] fire-damp was responsible [illegible] effects of some great colliery [illegible] theory has been advanced that [illegible] fire-damp, is capable of causing a [illegible] experiments of this theory is [illegible] the past two years [illegible] scale, in a closed shaft. [illegible] have yet been published, [illegible] gunpowder shot [illegible] absence of fire-damp. [illegible] coal-dust in Mines [illegible] report, when published, [illegible] most important subject. [illegible] a danger [illegible] have been proposed [illegible] otherwise.

[illegible] it will be [illegible] used for this purpose.

[illegible] gunpowder [illegible] in the loose [illegible] gunpowder will [illegible] explosives: but the great

dangers arising from its use are being gradually appreciated, and H.M. Inspectors of Mines, in their last annual reports, almost unanimously agree that the time has come for the absolute prohibition of the use, in fiery and dusty mines, of gunpowder and dangerous dynamite compounds, especially as there are now in the market other explosives which are relatively very much safer, more particularly when detonated by electricity.

In France the mining authorities are more advanced on that subject than in this country, inasmuch as their Ministry of Public Works issued a decree dated August 1st, 1890,* prohibiting the use of blasting-powder in any fiery mine or in any dusty mine whose dusts are inflammable. The assigned reason for this prohibition being that :—

> In consequence of the experiments carried out under the superintendence of the Explosives Substances Commission it has been found possible to procure for use in mines, explosives which, although not capable of giving absolute security (which one can hardly hope to obtain from these materials), permit the attainment of a degree of safety which was hitherto deemed unapproachable.†

Dynamite, gelignite and other forms of gelatine explosives, when used bare, are as dangerous in the case of a blown-out shot as gunpowder; hence various contrivances have been suggested for reducing the temperature and quenching the flame given off at the moment of detonation. Chief amongst these contrivances is the Settle water-cartridge. This system of blasting may or may not be comparatively safe, but its main defect is that to ensure safety two separate elements are necessary, viz., the explosive and the bag containing the water. It can be easily understood that unless the greatest care is taken the element of safety may be wanting at the time the charge is fired; either the water has been omitted entirely, as appears to have been the case in the explosion which took place at Apedale colliery on April 2nd, 1891, whereby ten lives were lost; or it may have leaked away because the water-bag was burst or pierced while charging. Besides the above-named defects there is the necessity for drilling extra large holes and carrying a pail of water to fill the bags.

We now come to the more modern explosives: these are known as dual explosives, having nitrate of ammonium for their base. The decree of the French Minister of Public Works, previously referred to, permits the use of four different classes of mixture attaining "to a degree of safety which was hitherto deemed unapproachable"

The first, second, and third mixtures are respectively dynamite No. 1, blasting-gelatine, and guncotton, each mixed with nitrate of ammonium, whilst the fourth is a mixture of dinitro-benzole and nitrate of ammonium.‡

* *Trans. Fed. Inst.*, vol. ii., *Appendix*, page 161. † *Ibid.*, page 159.

‡ *Ibid.*, page 160.

As regards the first-named mixtures the Home Office authorities refuse to license explosives of this kind, and report thereon as follows :—

It will be noticed that, while the addition of various ammonium salts to dinitro-benzole has been sanctioned, the addition of ammonium salts, other than the carbonate, to explosives containing gun-cotton or nitroglycerine, has always been reported against. The reason is this: all ammonium salts, especially when exposed alternately to moist and dry air at slightly elevated temperatures, lose traces of ammonia and become acid. Now, nitro compounds, like dinitro-benzole, are little, if at all, affected by traces of acid, and under such circumstances show no tendency to spontaneous decomposition which might lead to ignition or explosion. Nitro compounds like gun-cotton and nitroglycerine (more strictly speaking nitric ethers), on the other hand, are seriously affected by traces even of acids, especially strong mineral acids, and decomposition once started goes on and ultimately leads to total decomposition, which may end in ignition or explosion. Hence ammonium salts exert no dangerous action on true nitro compounds, but may fatally affect the stability of nitric ethers, like gun-cotton and nitroglycerine.*

The above extract, although bearing purely on the chemical aspect of the mixtures first referred to, is interesting, inasmuch as it only leaves the fourth mixture, consisting of dinitro-benzole and similar compounds with nitrate of ammonium, available for producing an authorized safety explosive of this class in the United Kingdom.

Before proceeding, the author would like to name certain other regulations in the French decree, which have an important bearing on the use of safety-explosives :—

The worker is forbidden to use . . . any explosives other than detonating explosives complying with the following conditions :—1st. The products of their detonation should not contain any combustible matter, such as hydrogen, carbon monoxide, solid carbon, etc. 2nd. Their temperature of detonation . . . should not exceed 1,900 degs. C. for explosives used in stonework, nor 1,500 degs. C. for those employed in coal-getting.

The stemming of the explosives . . . should be carefully made with plastic matter, so as to avoid blown-out shots; the length should not be less than 8 inches for the first 1,543 grains of charge, with the addition of 2 inches for each 1,543 grains additional, and should at all times exceed 20 inches.

The detonation of the cartridge should be caused by a detonator strong enough to assure the detonation of the explosive even when unconfined.†

The author will now consider a safety explosive of the fourth type officially recommended in France, which, as explained before, consists of a mixture of dinitro-benzole and nitrate of ammonium, and is the only one of the four types recommended which can at present be legally manufactured in the United Kingdom. As an example of this type, the author will describe roburite for the following reasons :—(*a*) Because it was the

* *Report of H.M. Inspectors of Explosives*, 1890, page 19.

† *Trans. Fed. Inst.*, vol. ii., *Appendix*, page 162.

first of this type of explosive manufactured in England, and is now very extensively used, and (*b*) because this explosive has been the subject of several scientific and impartial investigations, and therefore more is known about its properties than of any similar explosives.

Roburite was invented by Dr. Carl Roth, of Berlin, in 1886, and was patented and its use authorized by the Home Office in this country in 1887. A factory was erected for the manufacture of the explosive in the same year, was fully licensed by the Home Office in May, 1888, and started the manufacture and sale of roburite at once.

Roburite consists of an intimate mixture of chloro-dinitro-benzole and nitrate of ammonium. The chlorine is intended as an additional flame-quenching gas. The explosive is put into waterproofed cartridges to suit all requirements, and the sizes range from $\frac{7}{8}$ to $1\frac{3}{4}$ inches in diameter, and weights vary from 1 to 16 ounces.

As might be supposed, the introduction of a new explosive (although mining engineers and the public had been long clamouring for a safer explosive than powder or dynamite) was not all that was required to ensure its success. Colliery managers before introducing it into their mines put it to many severe tests, and an apparatus was erected near Wigan to produce the effect of a blown-out shot into an artificial mixture of fire-damp. The results of these tests are recorded in a paper by Mr. Jas. Hilton.* These tests were made at night, and seven shots of roburite tamped with from 4 to 7 inches of clay, and sometimes coal-dust, were fired into the fire-damp without igniting it. In looking through the details of these experiments, such remarks as the following are appended to each test:—Gas not ignited; no flame or sparks seen; gave a light but no flame, etc. The author would call the particular attention of the members to the latter remark, as some experiments with roburite were made at the Bent colliery before a committee of the Mining Institute of Scotland in 1888,† and a blown-out shot was purposely produced, when a light was seen. Whereas experiments have been made when fire-damp was known to be present, and a light was seen, but was not followed by an explosion of the fire-damp, it seems to the author that the light is not due to a true flame, but to the reflection of a halo of light formed at the moment the detonating wave is started, and that this is incapable of igniting an explosive mixture of gases. That this is true may be proved by taking a cartridge one-half filled with gunpowder and the other half filled with roburite

* *Trans. Manchester Geol. Soc.*, 1889, vol. xx., page 92.

† *Trans. Min. Inst. Scotland*, vol. x., page 132.

placed directly on the top. On suspending the cartridge and detonating the roburite, the gunpowder does not become ignited, but is scattered about by the force of the explosion.

We have seen from the extracts already quoted from the French decree that the conditions specified for a safety explosive are that the calculated temperature of explosion must be below a certain temperature. From this it would appear that even although a flame should be seen, if such flame were below the given temperature, still no ignition of fire-damp would follow. Another point, too, in the French report is that the duration of the temperature has an important bearing on the subject, and even although hot enough to ignite gas, would not do so if not long enough in contact with it. The writer has been told that it is possible to ignite fire-damp with heated gases which give no visible appearance of heat.

Much has been said about the fumes of roburite, and at several places the workmen raised objections to the use of the explosive on that account, although from more recent experience there can be no doubt that prejudice in favour of blasting-powder was at the bottom of these complaints.

The question of fumes has been investigated by two separate scientific committees—the first in Lancashire in 1889, the members of this committee being Dr. N. Hannah, Dr. C. J. Mouncey, and Prof. Harold Dixon, of Owens College, Manchester; * the second committee, appointed in 1889, by the Durham Coalowners' and Miners' Associations, with Mr. T. Bell, H.M. Inspector of Mines, as chairman, and Prof. Bedson and Drs. Drummond and Hume as professional advisers.† Both of these committees arrived at practically the same conclusions, viz., that the fumes of roburite were not more injurious to health than those of gunpowder. The report of the Durham committee, moreover, called attention to the fact that the fuze was responsible for some of the deleterious fumes, and many members will no doubt have noticed the difference in the quantity of smoke between a roburite shot fired by fuze and one fired by electricity.

As to the efficiency of roburite in mines it may be stated that by the kind permission of the owners and managers, trials have been made of roburite in about fifteen of the coal-mines in Lanarkshire, as well as at the shale-mines at Broxburn and Pumpherston in West Lothian, and in all cases with marked success.

* *Trans. Manchester Geol. Soc.*, 1889, vol. xx., page 329.

† *Trans. Fed. Inst.*, vol. ii., page 368.

The question of a safe method for igniting the detonator in firing a safety explosive is a very important matter. It appears on the face of it absurd to fire a safety explosive by fuze, which is practically the same as a naked light, as the spit of a fuze will easily ignite gas, and indeed has been known to do so on many occasions, and moreover, the tape fuze gives off noxious fumes.

The Bickford shot-igniters were introduced to make firing by fuze safer, as the first spit of the fuze takes place in the tin cap which contains the igniting composition. Still, even supposing that this contrivance is otherwise efficient, is there no risk of the smouldering fuze being projected when the shot is fired? The writer believes it to be a fact that this does take place, and that the fuze may brighten up in its flight and be a source of danger.

Another method suggested in Austria, but not to the author's knowledge used in the United Kingdom, is the Lauer frictional detonator. By this method of firing, an action somewhat similar to that used in the Christmas cracker produces the explosion, only the operator stands at a distance and pulls a string.*

Firing the charges by electricity is, the author thinks, admitted on all hands to be the safest, and besides the other advantages it possesses, a very important one is that shots cannot hang fire as is sometimes the case when using fuze, and there is less smoke.

There are two distinct types of electric fuzes used to produce an electric detonator viz., high and low tension. In the former case the priming composition is ignited by a spark, in the latter the heating of a hair-like platinum bridge by the resistance offered to the passage of the electric current ignites the composition which fires the detonator. The high-tension fuze is best known to mining engineers, but the low-tension fuze is now coming into more extended use.† Some authorities advocate the latter, because it can be tested by galvanometer, whereas the high-tension fuze cannot. This facility of testing would certainly be of great advantage in firing a large blast, where a number of charges had to be fired simultaneously, but in colliery work where only single shots are fired as a rule, the author thinks that either class of fuze is equally good.

In order to secure the best results from electric blasting too much attention cannot be paid to the electric appliances. The exploder should have a good surplus of power, so as to minimize the risks of a miss-shot,

* *Trans. Fed. Inst.*, vol. ii., *Appendix*, page 153.
† *Ibid.*, vol. ii., page 553.

and should be kept in good condition. The cable should also be good and, in case of a miss-shot, should be overhauled to see whether either of the wires has been broken or short-circuited. In making the connexions the wires should be clean, so as to obtain good metallic contact, and should be twisted firmly together. If proper care be taken, the writer believes that there would be fewer failing shots with electricity than with fuze.

All high or detonating explosives are fired by a detonator, some explosives are more sensitive than others, hence they require different powers of detonator to fire them efficiently. It is a waste of energy to use a detonator very much stronger than is necessary to start the detonation of the explosive, but it is far better to err on this side than to attempt to use with an inert explosive a detonator intended for a sensitive explosive. Thus, while a roburite detonator could be used to fire dynamite efficiently, a dynamite detonator would probably only scatter the roburite without detonating it. The French Government recognized the importance of this point in the regulations issued for the use of safety-explosives in lieu of blasting-powder, when they said :—

> The detonation of the cartridge should be caused by a detonator strong enough to assure the detonation of the explosive even when unconfined.*

The author desires to lay special stress upon this matter, as to his knowledge many complaints as to miss-fires of some of the more inert explosives have certainly been due to the use of too weak detonators.

DISCUSSION UPON MR. JAS. HAMILTON'S PAPER "ON THE REPORT OF THE ROYAL COMMISSION ON MINING ROYALTIES."†

The CHAIRMAN, in moving a vote of thanks to Mr. Hamilton for his paper, said those who objected to royalties knew least about them. He was satisfied that the payment of royalties in some form or other could not be avoided. He then declared the discussion closed.

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* *Trans. Fed. Inst.*, vol. ii., *Appendix*, page 162.

† *Trans. Fed. Inst.*, vol. vi., pages 9 and 381.

DISCUSSION UPON MR. ROBERT MARTIN'S PAPER ON "THE MID-LOTHIAN COAL-BASIN."*

The CHAIRMAN asked if the workings at the Niddrie collieries, had reached the bottom of the basin, where the seams would be found to be flattened out.

Mr. WM. ARCHIBALD (Cambuslang) said that in 1888 a valuable paper was read on the subject of the working of these vertical coal-seams by Mr. Hugh Johnston before the Institute†.

The CHAIRMAN said that the basin was deeper at the Niddrie collieries than at the Lothian Coal Co.'s or the Shotts Iron Co.'s collieries, but it was generally considered that the Niddrie workings would soon flatten out.

The discussion was then adjourned.

DISCUSSION UPON MR. JOHN HOGG'S PAPER ON "COAL-WASHING AT NORTH MOTHERWELL COLLIERY."‡

Mr. D. G. DUNN (Cambuslang), referring to the dirty condition of the water in the Clyde, asked if persons using coal-washers kept sufficiently before them the matter of reducing to a minimum the amount of dirt they passed into the river Clyde? For some time past it had been polluted, and many complaints were being made. His opinion was that much of the pollution might be prevented.

Mr. A. FAULDS (Cambuslang) said they had always thought that water was filtered by being passed through dross or ashes. He did not think the pollution was so bad as was represented, and was certainly not so injurious as the sewage that came from some of the towns on the Clyde.

Mr. A. M. GRANT (Kilmarnock) said that he had inspected the North Motherwell washing-plant, and he did not think there was a finer one at work in Scotland, England, or Wales. Could Mr. Hogg give them some indication of the cost of the machinery and the cost of cleaning?

Mr. HOGG said the cost of the whole erection, including all the buildings, was £9,580, and that also included the removal of an old building. The cost of the buildings was £2,000, and the washer cost about £7,600. He had no doubt, however, that a modified building could be erected at a lower rate. If members went to the outlet of their

* *Trans, Fed. Inst.*, vol. vi., page 388.

† *Trans. Min. Inst., Scotland*, vol. x., page 204.

‡ *Trans. Fed. Inst.*, vol. vi., page 393.

water into the river Calder at Bardykes, or to the river Clyde at North Motherwell, and examined the water, they would find that it was perfectly pure.

Mr. ARNOTT asked if both machines were of the same capacity?

Mr. HOGG replied that the one at North Motherwell colliery had a capacity of 1,500 tons, and the one at Bardykes colliery of 800 tons, but the washers were practically the same. The material in the Bardykes trial was not weighed; the cleaned dross was weighed on leaving the machine. The rubbish they spread out and weighed after it had been allowed to dry for 20 hours. In a previous trial the quantity of dirt was found to be about the same—12 per cent. In the old washer they emptied out the dirt for a day and then weighed the whole day's rubbish, and the result corresponded with what he had just given.

Mr. ROBERT WADDELL (Glasgow) asked Mr. Hogg if, after the experience he had now gained, the complete plant, machinery, and buildings could not be put up at less expense?

Mr. GRANT was quite certain the same buildings could be put up at a third less cost.

The CHAIRMAN asked if there was any fault to find with the wooden tanks or worm-conveyers?

Mr. HOGG said up to the present time they had had no trouble, but they occasionally had to renew the screw of the worms. The wooden tanks required renewal now and again. At North Motherwell colliery the lining of the boxes stood for about a year. He had looked into the matter of cost, and he did not think they had paid too much for the building; but, if they chose to use a cheaper class of wood and put up lighter buildings, they might save money in that way, although he thought if it was worth while putting up machinery of this class, it was worth while putting it up in a substantial manner.

The CHAIRMAN said the ash in the unwashed gum coal was given as about 22 per cent., and in the washed pearl dross from 3 to 4 per cent., but the proportion of ash in the sludge was not recorded. In order to make an exact comparison, the amount of ash in the sludge should be given, as it contained a much larger percentage than the pearl dross, perhaps 15 per cent. He asked what was the advantage of the pyramid-shaped boxes or grader. It seemed to him, from a theoretical point of view, that they were of little advantage. He reminded the members of a paper read some years ago before the Institute by Mr. Rowan, on the principle upon which depended the settling of particles in water.* Mr.

* *Trans. Min. Inst., Scotland*, vol. ix., page 185.

Rowan showed that the rate of settling depended partly on the specific gravity and partly on the size of the particles. It was for this reason that the sizing of dross before washing was of such great importance. According to this theory, the pyramid-shaped boxes would be of little value. They would find a separation in the different divisions of particles which settled at the same rate, and which were therefore the most difficult to separate from each other. The arrangement was adopted, he understood, owing to the difficulty of sizing small dross with riddles. But if they were to size into two sizes, and subdivide again into other two sizes, they would have perhaps a better result than that produced by these boxes. He should like Mr. Hogg to examine the boxes and ascertain whether what he said was not correct.

Mr. HOGG said that no doubt along with larger pieces of coal there would be smaller pieces of rubbish, but they had had no difficulty on that score. If they examined the different gum-washing boxes they found both coal and rubbish graded. Like any other particles carried forward by water, the heavier particles, because of their size or higher specific gravity, settled first. When they had the old dross-washer they first screened the coal and took out the gum for the fires, and in order to get rid of the water before leading the gum to the fire-doors, they made two boxes just like these pyramid-shaped boxes, although they had not seen them then, and by that means the gum was drained. He noticed that the first box caught the round gum, and the second caught the fine gum, so fine that it came out at the time like smudge. The better the coal was sized the better was the washing done, and doubtless a more minute classification could be got with riddles, as they would have the size of the rubbish corresponding with the size of the coal. Still, he did not think it would be any improvement, by reason of the mechanical difficulty. However, since the matter had been brought before him, he would make a more minute examination, and let them know the result.

Mr. W. THORNEYCROFT (Hamilton) remarked that in the statement of results the cost of repairs appeared to him very small, and the amount charged for depreciation was not mentioned; and he thought that the cost of replacing wearing parts in such a machine would be greater unless provided for by a heavy depreciation charge. In the trial washing of dross from a neighbouring colliery, he would like to know if there was not a certain amount carried away by the water? The loss in that way was sometimes considerable. He had a little experience in washing dross brought from the collieries with a Robinson machine-washer, and the loss was a distinctly appreciable quantity. Every class

of dross seemed to have a tolerably constant factor of loss of its own. Binged dross always showed a greater percentage of loss than fresh dross, and good ell dross showed the least loss. The dross showing most loss was splint dross from pits where a few inches of soft falling was found above the coal. This falling is a light sandy blaes of a very friable character, especially so from stooping places, and he thought it would be found troublesome in any machine. In passing through the washing process, the little clay it contains is washed out, and a considerable portion of the remaining material is carried away by the water in the form of a very fine sand. The clay makes the water milky and unsuitable for use over and over again, but the sand settles down in the ponds and stores, more or less quickly. Experiments were made to find out exactly what became of the loss and measured quantities of dirty water were taken at intervals during the trials of various lots of dross of about 100 tons each. The water was allowed to settle, the time taken being noted, and the deposit weighed in two portions, first fine sand and coaly matter, and second the clayey portion. This latter portion took so long to settle that with certain classes of splint dross acres of settling ponds would be required to clear the water. The sandy portion settled easily, and some of it was sent to an iron-foundry for trial as moulding sand, but was said to be unsuitable. He found that 20 to 33 per cent. of the total deposit, when dry, was carbonaceous matter. When the figures thus obtained were applied to the total quantity of water passed through the machine during each trial, he found that the result approximately balanced the loss.

Mr. FAULDS asked if the lubrication was not charged too low in the statement given by Mr. Hogg?

Mr. HOGG said the amount of the lubricator stated was the actual quantity used per week. As to the cost of upkeep, he went into it carefully, and he could not make it any more, but thought that the cost might become higher as the machine got older, worn-out parts possibly requiring replacing. All they lost by washing was the dirt, very little more going away. Out of 55 tons washed there was a loss of 8 cwts.,* but he could not say where it went to. When they started to wash with the old gravitation-washer in 1879, splint dross was selling at from 6d. to 9d. per ton, and when washed it sold for 2s. to 2s. 6d. per ton; it all went away as dross, there being no classification at that time. There was thus a gain, by washing it, of 1s. 4d. per ton.

The further discussion was then adjourned.

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* *Trans. Fed. Inst.*, vol. vi., page 396.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE MASON SCIENCE COLLEGE, BIRMINGHAM, DECEMBER 7TH, 1893.

MR. G. H. CLAUGHTON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of the Council Meeting were read and confirmed.

The following gentleman was elected:—

MEMBER—

Mr. WILLIAM BLANE, Mining Engineer, Johannesburg, Transvaal.

The following paper by Mr. Henry Johnson on "A New Method of Tamping and Ramming Bore-holes," was read:—

A NEW METHOD OF TAMPING AND RAMMING BORE-HOLES.

By HENRY JOHNSON.

Blasting has, for some time past, assumed an increasingly important position among the questions considered from time to time for the safer working of coal-mines, until at the present time it may be said to be one of the foremost. The exhaustive investigations of the late Mines Accidents Commission on the subject, the suggestions and recommendations of that Commission, and the subsequent stringent requirements contained in the present Coal Mines Regulation Act, founded upon this acquired knowledge, are all clearly indicative of the paramount importance as regards safety that is attached to the question of blasting in the working of coal. How many explosions owe their origin to the improper application of explosives and to blown-out shots, or how many thousands of lives have been lost in consequence, can never be known ; but there can be no doubt that past lax discipline in this particular branch of mining must be held responsible for a very large proportion.

Inefficient blasting may be principally attributed to the following causes :—(*a*) Incomplete cleansing and consequent amalgamation of explosive and coal-dust, or borings left in the borehole ; (*b*) the use of coal-dust, or under-clay mixed with coal-dust and fragments of coal, or under-clay mixed with fragments of hard clunch or rock, for stemming ; (*c*) the use of too much explosive and too little tamping ; (*d*) unequal strength of tamping, compact at bottom and loose at top and sides, in consequence of the rammer-head being excessively smaller in area than that of the bore-hole, and by its own weight always seeking the bottom of the bore-hole rather than the bottom, top, and sides.

It is therefore, with a desire to do something towards remedying these defects, that the writer has given this subject attention of a practical nature, and trusts it may appear with some useful effect. There can, he thinks, be no doubt that many blown-out shots, resulting in waste of labour, loss of explosive, and sometimes in explosions, do occur in consequence of utterly unsuitable and improper tamping being used by the workmen. It is notorious that colliers very often use most unsuitable tamping when they cannot readily procure clay, bind, or soft rock, and

that slack is sometimes used for this purpose; rough gritty tamping is also used, resulting in premature explosion. Loose tamping, even when of a proper nature, cannot be relied upon for uniformity, and at the best, in many ways, is inconvenient and difficult of application for stemming a hole, especially in holes inclining upwards. The compressed cartridge-tamping, when used in conjunction with the improved rammer, in the writer's opinion, does away with every existing objection and difficulty. It is a tamping made in cartridge-form to fit the borehole, and has a central hole for the fuse, and just in the same way that the compressed powder-cartridge or bobbin has so conveniently and safely superseded loose powder, so it is expected will the machine-made clay pellets supersede the rough and loose stemming.

The cartridge tamping is made with a small hand-press, which may be bolted to a shop bench and worked by a lad, the pressure requisite to compress a cartridge being not more than is necessary to bind it together for transit and handling. The author finds that the clay usually underlying the coal-seams is quite suitable for the purpose, and may be sent to bank for compressing into tamping-cartridges as required, or the press may be fixed near the pit-bottom. A stock of such tamping-cartridges, kept at each way-end and ready for use, should prevent improper tamping being used at any time.

It is a well-known fact that there are many instances, especially when the position of the bore-hole is inconvenient, of the hole being very imperfectly tamped with loose tamping, scaffolding and spaces being formed; but with a cartridge-tamping a hole in any position may be expeditiously and thoroughly tamped. The cost of compressing the clay into cartridges, is as follows:—In an actual trial (a press worked by a lad at 2s. a day) 1,620 cartridges were made, each $1\frac{7}{8}$ inches in diameter by 2 inches long, or sufficient for 135 holes, each containing 2 feet of tamping, at a cost of 0·18d. per hole, to which must be added royalty, and cost of press, all of which sinks into insignificance when compared with the advantages obtained.

Whilst the common rammer is no doubt to some extent suitable for pushing loose tamping into a borehole, it is quite unsuitable for ramming it up into a compact and sound barrier against the explosive, the presence of a fuze or cable-wire adding seriously to the difficulty, resulting very often in burst water-cartridges and severed fuzes and cables.

The improved rammer consists of a shaft carrying a head at one or both ends, of a diameter slightly smaller than that of the borehole, and slightly larger than that of the tamping-cartridge, the head having a central hole for the passage of the fuze. In ramming a hole, the fuze leading from the

explosive cartridge is passed through the central hole of the tamping-cartridge, and through the central hole of the rammer-head, and is held at the top side of the mouth of the hole (Fig. 1, Plate XV.). In this manner the tamping-cartridges are easily pushed into position and there broken up and perfectly rammed, the fuze or battery wire being maintained in a central position throughout the length of the hole, thus obviating abrasion against the wall of the hole, which is the case when the ordinary rammer is used.

A suggested new method of constructing a bore-hole has for its object the protection during the process of tamping of the water-cartridges and other explosives used in blasting operations, and the prevention of premature explosion of, or injury to, the cartridges or explosives.

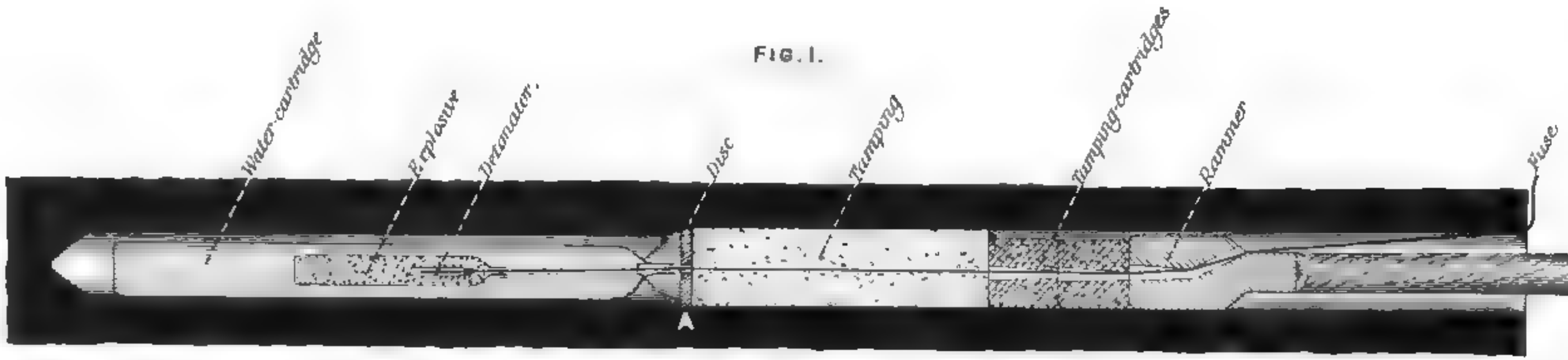
The method to be used in connexion with the blasting of coal by the use of a water-cartridge is as follows:—The bore-hole is made of two different diameters, at different parts, the inner end of the hole being of smaller diameter and shorter than the outer end, the inner end constituting the chamber for receiving the water-cartridge, and the outer and longer part being intended to receive the tamping. By making the bore-hole of different diameters, a shoulder is formed where the hole changes its diameter. For the purpose of protecting the water-cartridge from injury during the operation of ramming the tamping, a disc, having a hole at its centre, is fixed in the larger part of the bore-hole and against the shoulder. This disc may be made of wood, cardboard, or other hard material, and may be strengthened by being made convex or corrugated.

The operation of charging a bore-hole with a water-cartridge, and tamping and ramming the hole and exploding the cartridge, may be described as follows:—The water-cartridge is pushed into the inner and smaller part of the bore-hole, the fuze or battery wire attached to the water-cartridge is then threaded through the hole in the centre of the disc and through holes in one or more cartridge-tampings, and through the hole in the head of the rammer. The disc and tampings are then pushed up to the shoulder in the bore-hole, and rammed in the ordinary manner (Figs. 1 and 2, Plate XV.). The disc takes up a position at the shoulder in the hole, and constitutes a barrier between the water-cartridge chamber of the bore-hole and that part of the bore-hole containing the tamping. The disc is then fixed in position by ramming one or more tampings against it, the fuze or battery wire is threaded through more tampings, the hole is stemmed for an adequate distance, and the explosive fired in the ordinary manner. The employment of the disc gives confidence to the operator and results in his directing a maximum of force against the tamping.

Federated Institution of Mining Engineers
Transactions 1893-4.

To illustrate Mr. Henry Johnson's Paper on "A New Method of Tamping & Ramming Bore-holes."

Fig. 1.



Longitudinal Section of Machine-drilled Bore-hole.

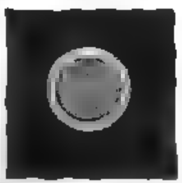
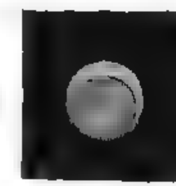


Fig. 2

Cross Section at A in Fig. 1.

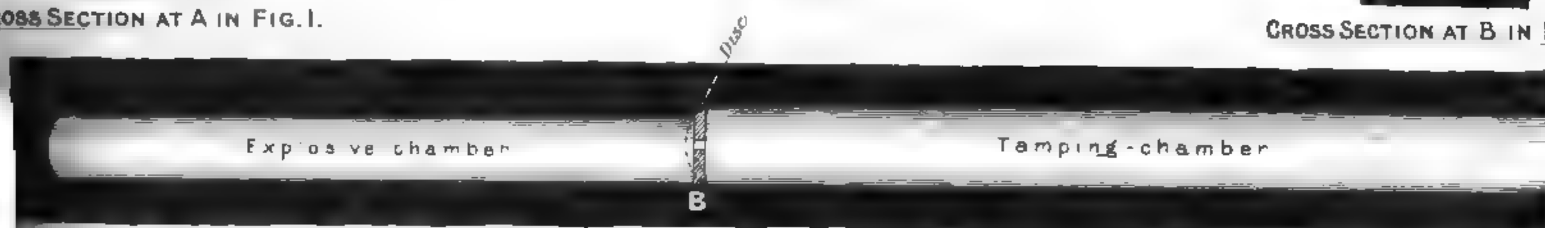
Scale 1 Foot to 2 Inches

Fig. 4



Cross Section at B in Fig 3.

Fig. 3.



Longitudinal Section of Hand-punched Bore-hole.

Although the method of blasting by the use of a water-cartridge has been described, the method is applicable to blasting operations generally, and to those in which explosives are used without water-cartridges being employed.

The suggested improvements were intended to apply only to machine-drilled bore-holes. After personally conducted trials, the writer finds that a hand-punched bore-hole can be made by an ordinary miner, of sufficient regularity to form a shoulder against which to fix a disc-partition for separating the explosive-chamber from the tamping-chamber, and capable of withstanding the pressure requisite for ramming the tamping (Figs. 3 and 4, Plate XV.).

The trial bore-holes were made with an ordinary hand punch, with different sized bits at either end, and only requiring to be reversed, after the part of the hole of larger diameter had been made by the larger bit, in order to drill the inner and narrow portion of the bore-hole.

The advantages gained by the improved methods of blasting are :— (*a*) A decreased liability to blown-out shots through the stemming being more perfect and secure ; (*b*) there is no risk of cutting either fuze or battery wire, which causes work to be suspended, and leads miners to the frequent temptation of unramming shots, resulting sometimes in premature explosion of the charge and loss of life ; (*c*) there is no risk of the water-cartridge being broken ; and (*d*) a perfect stemming is secured, obviating the risk of premature explosion, through use of unsuitable tamping as now used.

Mr. I. MEACHEM, Jun., read the following paper on "Ancient Mining at the Coppice, Sedgley" :—

ANCIENT MINING AT THE COPPICE, SEDGLEY.

By I. Meachem, Jun.

The Coppice colliery is situated on the northern slope of the Woodsetton synclinal, forming in fact the lip or edge of the basin formed by the Wren's Nest Hill on the south and Hurst Hill on the north, the intervening valley containing the thick coal now being worked by the Earl of Dudley at the celebrated Claycroft open-works.*

At the particular spot where these ancient workings were discovered in 1890, the coal lies at the comparatively low angle of 1 in 27. This angle would be most favourable to the early miners, as they would be able to work a fairly large area without being troubled by the mines rapidly dipping away to what to them would be inaccessible depths.

In the early part of 1890, Mr. Grainger Smith determined to work the thick coal as an open-work, and operations were commenced at the lane immediately opposite the Coppice house (Fig. 1, Plate XVI.). In removing the soil from the garden and lawn there was no indication whatever of the ground having been disturbed, the soil being about 15 inches in thickness, and apparently as even as when laid by nature's hand. When the soil was cleared away it was apparent that circular openings had been made into the measures underneath, and these had been filled up again. It was also found, after the coal had been removed from round these circular markings, that shafts had been sunk through the coal and then filled up again. The shafts had been filled up with coal, slack, and spoil, and after the removal of the coal presented the appearance of cones of thick coal-gob (Fig. 2, Plate XVI.).

The fact of the shafts being filled with coal and slack was rather puzzling, till a closer examination showed they had not been sunk for coal, but for ironstone, as evidences of the search for the ironstone immediately below the thick coal were clearly visible. After a shaft had been sunk, the ironstone was worked from the shaft as far as practicable without timbering, then another shaft had been sunk, the first shaft being filled with the coal and slack wrought from it, and the reason of the shaft being wider at the bottom than at the top was that a greater area of ironstone

* *Trans. Fed. Inst.*, vol. iii., plate XXIX.

should be uncovered. The ground was fairly well covered by these shafts, which were from 15 to 20 feet deep, 5 feet in diameter at the top, and 12 feet in diameter at the bottom.

An attempt had been made to drive a head in the stone measures, but as timber was not used it was very small; and it was impossible to ascertain the length as it was nearly closed.

A short distance from the shafts, about 4 feet below the surface, and 18 inches above the top of the thick coal-seam, a basin-shaped hollow was found 4 feet in diameter, 2 feet 9 inches deep, lined with clay 6 inches in thickness, which had evidently been burned to a brick red colour, and it contained coal-ash, charcoal, calcined iron-ore, burned shale, etc. This basin had evidently been used as a calcining-furnace, in which the iron-ore had been calcined, but whether the fuel used had been wood or coal was not easily determined. The shafts having been filled with coal showed the slight value in which coal was held, while the presence of charcoal in the furnace was evidence of wood having been used for fuel.

The writer is inclined to think that this interesting discovery is one of the earliest evidences of mining in this country, more especially as the soil over the old workings bore no sign of having been disturbed; as the coal was not considered worth using (only the ironstone being considered of value); and, lastly, as no timber had been used in these mines (in all the area explored not the faintest vestige of timber was seen).

The shafts being sunk close together showed that it was not so much a question of ventilation as the danger of getting ironstone without timbering the roof that had caused the workings to be confined to a distance of not more than 8 or 9 feet from the shaft, the average being about 6 feet, beyond which the workings would become dangerous without timber being set.

No tools of any kind were discovered; this is to be regretted, but may be accounted for by the small area of workings from each shaft.

The writer offers no opinion as to the particular age in which these workings were made; he simply record the facts and particulars of their discovery, and trusts that some of the members may be able to settle that question.

Mr. Glennie said it was evident from what the writer said as to the filling up of the shafts with coal and slack that the workings had been carried on at a very early period in the history of mining. At Ponkey, near Ruabon, ironstone had been worked in a precisely similar manner by

means of bell-pits. The workings extended over a large area of ground, and shafts had been sunk through the coal, but were not filled up again with coal and slack. The shafts were situate close together, similar to those described by Mr. Meachem. The bell-pits alluded to in the paper must have been worked at an earlier date. Ponkey ironstone was smelted with coal from early in the last century.

Mr. ALEXANDER SMITH (Secretary) said the ancient mining described in the paper took, no doubt, place prior to the time of Dud Dudley.

Mr. W. B. SCOTT thought that the ancient date of such workings as those described by Mr. Meachem was a matter of much interest. Some bell-pits probably dated as far back as the time of the Romans, and not later than the fourth century. Shafts were sunk to the coal and through the coal to the ironstone which lay below, and the working of that ironstone was carried on at a very much earlier period. Charcoal had been used to smelt the ore, as the coal was then of no value for that purpose. If the members read the ancient history of mining, they would find that the working of pits in the way described was well understood. Bell-pits presented features of great interest, and especially with regard to the early development of mining. He would expect that bell-pits, such as those described by Mr. Meachem, were probably worked by the Romans.

Mr. MARTIN said that many bell-pits were found when the Eccleshall reservoir was being made.

Mr. F. G. MEACHEM observed that he accompanied his brother in the visit to the ancient workings at the Coppice, Sedgley. The most interesting feature to him was the crudeness of the method of mining, which caused him to believe that they were very old workings. Mr. Scott considered that they might be regarded as of the time of the Romans, but he was inclined to trace them back to prehistoric times. The fact of the coal being actually abandoned in the workings showed that fuel was not the object sought, but the ironstone that lay beneath the coal; and when they considered the limited area mined and the crude method employed, there could only be a small quantity of iron obtained in such a manner. Very little iron could be used when so small a supply met the demand. He should certainly think that the mine was worked early in the Iron Age, the latest of the prehistoric ages. He had no hesitation in saying that the first iron was probably derived from hematite-ore, for the dwellings of early man were in caves; and those caves might be seen to-day in the Mountain Limestone of various parts of England, and it was from those beds that hematite-ore was first mined. The cave-dwellers in making fires would make use of stones to encircle or support the fuel, and

To illustrate Mr. I. Meachem, jun's Paper on "Ancient Mining at the Coppice, Sedgley."

Fig. 1. Plan

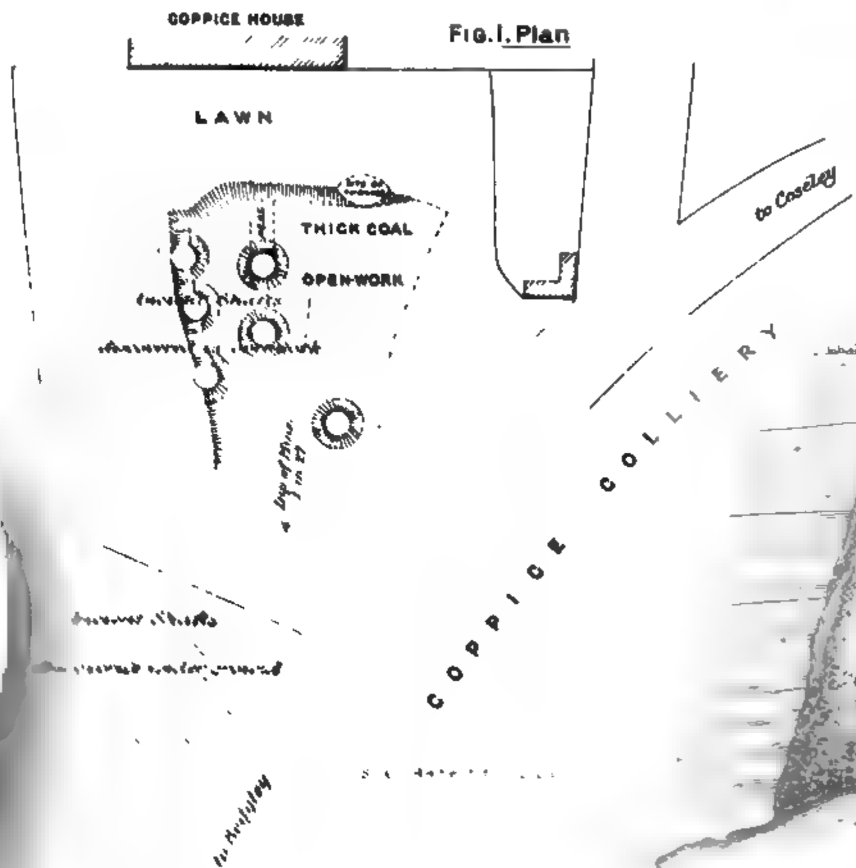
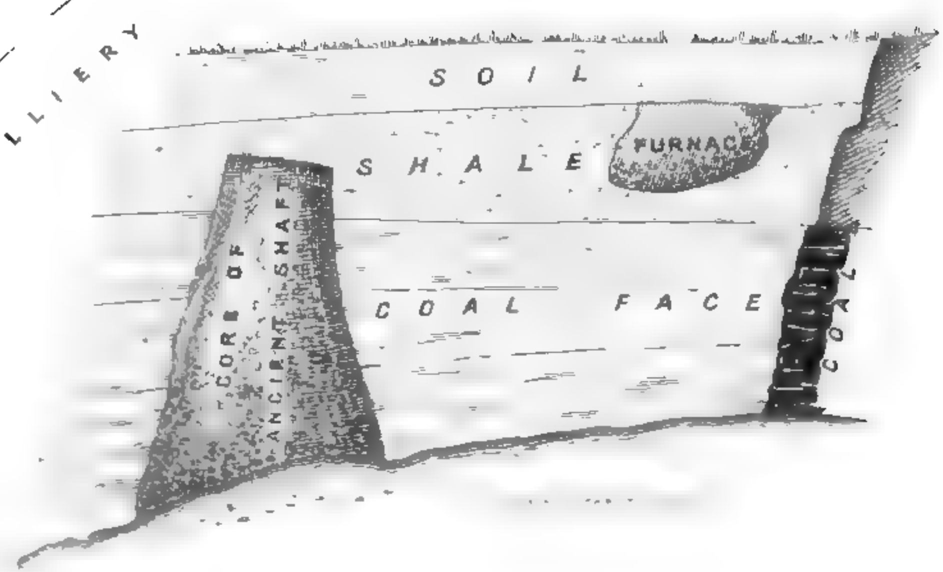


Fig. 2. View of Open-work.



hematite-ore being among the stones, gave up to the fire the metal it contained. This fact being observed, experiment would soon lead up to the systematic making of iron. He considered he was right in asserting that accident first led the way in human discovery, for there had been no experience to point the way. The superiority of the new metal, iron, over bronze gradually asserted itself, and the Stone and the Bronze Ages finally closed. A similar set of circumstances led to the use of clay-ironstone, such as that yielded by the mine at Coppice Hall and other places. It had often occurred to him that the presence of iron pyrites in the clay ironstone first led man to suspect the presence of a metal; and subsequent experiments resulted in iron-making, and of course in mining for ore. It was well known that at a very early period the Phœnicians came to this country for copper and tin, and they must have had good tools to work such mines. That fact alone would put such a rudely primitive mine as that which had been described by his brother among the early attempts of prehistoric man. The peculiar form of those shafts was needed to enable men to place a ladder in them as a means of descending and ascending. The ore would be carried on the back in a bag or basket, and a small supply only could be got from such a mine and by such means. He certainly thought they had before their notice an account of one of the earliest iron-ore mines in England. Such mines would not yield sufficient metal for the uses of the early Briton as the Roman found him when he first invaded this country; nor would those mines yield to the Roman a supply for his many needs.

The President moved, and Mr. John Williamson seconded, a vote of thanks to Mr. I. Meachem for his paper, and the meeting terminated.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,

NOVEMBER 27TH, 1893.

MR. ROBERT H. COLE, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected :—

MEMBERS—

Mr. WILLIAM ARMSTRONG RICHARDS, Sandbach.
Mr. JAMES TONGE, Mining Engineer, Bolton, Lancashire.

STUDENT—

Mr. FRANCIS W. KNIGHT, Mining Student, Newcastle, Staffordshire.

The SECRETARY read the Annual Report of the Council as follows :—

REPORT OF THE COUNCIL.

Having already held the usual meeting, this report must naturally be very brief. Since that date (February 27th) four ordinary meetings have been held., viz., in the months of March, April, May, and September, and the meeting of The Federated Institution of Mining Engineers held in June in London; while in August an excursion was made to the Manchester Ship Canal. At the ordinary meetings papers were read on the following subjects :—

"Electric Lighting and Transmission of Power," By Mr. W. M. Mordey.
"The Lockett and Gough Direct-acting Pump." By Mr. Lockett.
"The Use of Petroleum, Paraffin, and other Mineral Oils Underground." By Mr. W. N. Atkinson.
"The Sussmann Electric Lamp." By Mr. V. C. Doubleday.

It is a matter of regret that only one of these papers was contributed by a member of this Institute. Discussions have also taken place upon longwall working, the Lockett and Gough direct-acting pump, and the use of petroleum, paraffin, and mineral oils underground. Probably the numerous papers contributed to The Federated Institution of Mining Engineers make it more difficult for the members of this Institute to select subjects ; the Council, however, suggest that there may be many matters of local interest occurring to the members that could, with a brief description of the same, be brought forward for discussion, and much valuable information obtained.

The register again shows a decrease, the following being the membership :—Life Member, 1 ; Honorary Members, 7 ; Federated Members, 163 ; Non-Federated Members, 11 ; total, 182 ; as compared with 214 last year. The decrease was partially caused by resignations, but the Council have to deplore the loss, by death, of two of the oldest members, Mr. Robert Heath and Mr. Charles J. Homer. Both gentlemen were largely interested in the coal and iron industries of North Staffordshire and did much to develop the same ; they were also ever ready and willing to support any worthy cause. The last-named gentleman took an active interest in the Institute, occupying the presidential chair in the years 1874 and 1875, and he also contributed a valuable paper on the North Staffordshire coal-field.

The PRESIDENT said the annual meeting was held that day so as to come after that of The Federated Institution of Mining Engineers, whose financial year ended in July ; and it had been decided to have their annual gathering towards the end of the year, instead of in February as heretofore.

DISCUSSION ON PROF. F. CLOWES' PAPER ON "A PORTABLE SAFETY-LAMP WITH ORDINARY OIL-ILLUMINATING FLAME, AND STANDARD HYDROGEN-FLAME FOR ACCURATE AND DELICATE GAS-TESTING."*

Prof. CLOWES said it had long been known that the hydrogen-flame was the most accurate and delicate gas-testing flame, but it also possessed the great advantage of standing rough swinging and even dropping the

* *Trans. Fed. Inst.*, vol. iv., page 441.

lamp without being extinguished, powerful currents of air could not affect it, and ordinary after-damp did not extinguish it. It yielded only to the effect of an inflammable or explosive mixture. The hydrogen-flame, therefore, when used as an auxiliary flame to the oil-flame in the lamp in awkward places, or in bad air which had to be traversed, saved the loss of the flame. The ordinary oil-flame, and the alcohol-flame, readily suffered extinction under conditions which did not affect the hydrogen-flame. This lamp enabled a miner to guard absolutely against the loss of his light in any conditions to which he might be exposed in the mine, with the sole exception of exposure to a dangerously inflammable or explosive mixture, under which circumstances it was universally granted that every flame should be extinguished in the interests of safety from fire and explosion. The bars of the measuring-scale* did not correspond with the tops of the hydrogen-flame. It was necessary to let the caps project a little beyond the bar. The bar was not placed at the top of the cap, but about 0·2 inch below it, so that the cap might render the bar visible.

Mr. MAKEPEACE said that the tip of the flame-cap could be seen when it was well defined.

Prof. CLOWES replied that the bar could not be seen against the tip.

Mr. MAKEPEACE asked if the cap indicated by 5 per cent. of gas on the oil-flame was of exactly the same height as that shown by 1 per cent. on the hydrogen-flame?

Prof. CLOWES replied that they were of exactly the same height. There was no fear of melting the glass in the hydrogen-lamp, as the tip of the flame in the ordinary way never touched the glass. They had never known a glass to be cracked, far less softened, by heat. There could be no inconvenience in that respect if the lamp was used in the ordinary way.

Mr. E. B. WAIN asked whether it was to be understood that the smallest percentage of gas that could be detected with an oil-flame was 2 per cent.?

Prof. CLOWES—They began their measurements with the oil-flame with 2 per cent.; and with a black background they could read the cap distinctly. Two per cent. was a faint cap; 3 per cent. the same size, but more distinct; but they never got below 2 per cent. with the oil-flame. With the hydrogen-flame, ½ per cent. was easily seen.

Mr. WAIN said he had been recently testing for gas with the Stokes spirit-lamp,† which gave a distinct cap with 1 per cent., and there was a

* *Trans. Fed. Inst.*, vol. vi., page 179, Fig. 2. † *Ibid.*, vol. v., page 462.

distinct cap of $\frac{1}{8}$ inch on an oil-flame. The oil-flame was a modification of the Grey lamp, with a flat wick, burning a mixture of colza and paraffin oils.

Mr. Makepeace said he had seen a distinct cap on an oil-flame, when the Pieler lamp showed the presence of $1\frac{1}{2}$ per cent. of gas.

Prof. Clowes said he had frequently seen the caps produced in the lowest percentages with the Pieler lamp, and those with the colza-paraffin flame. They were seriously interfered with by the fact that a faint cap was seen in air free from gas, over both the alcohol and the paraffin-flames.

Mr. Makepeace said he had no hesitation in saying that he had seen a cap indicated on the oil lamp of less than 2 per cent.

Mr. Spruce proposed a vote of thanks to Prof. Clowes for his attendance and his explanations respecting the hydrogen-lamp.

Mr. Makepeace (Government Inspector of Mines), in seconding the motion, said he was pleased with the useful, portable, and practical form which had been adopted for the lamp. He had not had an opportunity of trying the lamp, but from reports he had no doubt it was the most useful, handy, and practical form of testing-lamp that had been brought out. Several others were clumsy, unwieldy, and unsafe to deal with. He had used the Pieler lamp, and the lamp now before them combined the advantages of the Pieler lamp and the ordinary lamp. He considered Dr. Clowes was to be congratulated upon the lamp that he had introduced.

The vote was heartily adopted, and was briefly acknowledged.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, DECEMBER 18TH, 1893.

MR. ROBERT H. COLE, PRESIDENT, IN THE CHAIR.

The minutes of the previous Annual General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected :—

MEMBERS—

Mr. T. VAUGHAN HUGHES, Newcastle, Staffordshire.
Mr. J. J. PREST, Shelton Steel and Iron Company, Stoke-upon-Trent.

The following were nominated for election at the next meeting :—

MEMBER—

Mr. PATRICK BRENNAN, Colliery Manager, Chesterton, Staffordshire.

STUDENT—

Mr. JOHN JAMES OFFER, Adderley Green Collieries, near Longton.

Mr. R. H. WYNNE then read the following paper on "The Application of Mechanical Arrangements in Underground Operations" :—

THE APPLICATION OF MECHANICAL ARRANGEMENTS IN UNDERGROUND OPERATIONS.

By RICHARD H. WYNNE.

At no period in the history of modern coal-mining has there been so great a necessity as at the present time for the thorough and careful consideration of the best modes of applying approved mechanical arrangements at the surface, in shafts, etc., of economizing manual labour, and of dispensing with horse-power underground.

It is not intended to give anything like detailed descriptions of various methods in use, nor to propound dogmatic opinions as to the merits of one system as opposed to another system of applying power, but to deal with the question in a very general way from personal observation, together with extracts from and references to various writers and transactions of the different institutions of mining engineers. It was also intended to give some idea of the comparative cost of erection of works and laying down plants, as well as the probability of relative freedom from accidents likely to be attained by the use of mechanical means as compared with horse-power or manual labour.

It will be apparent to everyone that a thorough consideration of the circumstances of each case is imperatively necessary before adopting any particular system, and that no hard and fast line can be laid down; therefore a short digest of information obtained from various sources may be found useful, although given in a general and comprehensive form.

The subject under review may be conveniently classified, as far as regards motive power, under the following heads:—

1. Horse-power.
2. Steam.
3. Compressed air.
4. Electricity.
5. Combustion of petroleum.

In making this division it appears somewhat anomalous that steam should be referred to as a separate motive power, but it is found in many cases that it can be used more conveniently and in a safer manner (although not perhaps quite so economical, as the prime mover for compressing air or generating electricity), than when applied direct, and for this reason steam is referred to as a distinct motive power.

Horse-power.

The greater depths to which it is now essential to sink in making new winnings naturally necessitates the acquirement of larger areas to be worked from one pair of shafts, and the conveyance of the coal over much greater distances from the working-face to the winding-shafts (Mr. Henry Lewis, during a discussion in 1881, stated that he expected to haul coal 3½ miles.*) Consequently, the necessity arises for the most approved system of underground haulage, the cost of which is well known to be one of the most important items in the production of mineral fuel. It is recorded by Mr. Nicholas Wood in one of the early volumes of the *Transactions* of the North of England Institute of Mining and Mechanical Engineers that the average work of a horse underground was about 32 tons conveyed by each horse one mile per day. Mr. Henry Fisher records † about 20 tons for each horse per day of 8 hours; Mr. Humble, of Staveley colliery, records a case of 54 tons being the work of each horse per day,‡ but this was probably under exceptional circumstances as to condition of road, gradient, etc. Therefore the limited quantity which can be conveyed by horses, the cost of their keep, liability to injury by accident, or cruelty of drivers, feeding them when only partially employed, replacing them when old or permanently injured, and wages of drivers, which are somewhat increased owing to statutory restrictions, leads to the conclusion that, as far as possible, the use of horse-power for the underground conveyance of coal (except for short distances, during the opening out of a colliery), and bringing the waggons from the face to hauling stations must be replaced by some more economical means of locomotion.

Steam.

Steam has already been referred to as the prime mover in compressing air and generating electricity; therefore it is most important to consider the economical production of steam power, whether applied direct or with the intervention of other machines. At the present time the Lancashire type of boiler, with two flues intersected by cross tubes, appears to be in most general use, and where erected under proper conditions such boilers are found to be economical steam-producers. There are several types of furnaces designed for the consumption of refuse coal, and even house refuse, with and without the addition of forced draught: amongst them may be mentioned the Meldrum, in which a small jet of steam is passed through a tube of special design,§ and the Perret system in which the

* *Trans. Chesterfield Inst.*, vol. ix., page 14.

† *Ibid.*, vol. xii., page 145. ‡ *Ibid.*, vol. ix., page 36.

§ *Trans. Fed. Inst.*, vol. iii., page 250.

blast is applied by a small fan under a pressure of $\frac{1}{2}$ to $\frac{3}{4}$ inch of water.* The Wilson gas-producer has also been used, for colliery purposes.† There are other important points, as well as the special kind of boiler to be used, which must not be lost sight of in providing for the economical production of steam, such as heating the feed-water, the use of well-constructed furnaces, careful firing, chimneys of proper height and internal area, covering the boilers and steam pipes, etc. It is recorded by Mr. C. S. Wardell, in a paper on "Economy of Coal at Collieries,"‡ that by covering a range of eight plain cylindrical boilers with common plastic clay, and when dry, the cracks filled up and the whole covered with two coats of gas tar, and by the steam-pipes being coated with a special composition, the temperature of the boiler-shed was reduced from 115 to 68 degs., the outside temperature being 60 degs. Fahr., and in addition the consumption of fuel was reduced from 12 lbs. to about 7 lbs. per horse-power per hour, thus showing how much may be done by simply reducing the radiation of heat from boilers.

In some cases, where a steam-engine is required underground, it has been found preferable to place the boilers underground also; but it is doubtful whether the advantage gained by having the steam-generator near to its work, with some economy in fuel, is not counterbalanced by the greater outlay in constructing large boiler-rooms with long stone drifts for flues, together with the risk of serious accidents which might arise from the coal (or shales associated with it) taking fire, and the possibility of grave results ensuing from the presence of flame in the upcast shaft of a deep and fiery mine.

There will probably be found an objection to the use of steam-engines underground, even when the boilers are placed at the surface, owing to the loss by condensation of steam in the pipes in the shafts, breakage of pipes by irregular expansion and contraction, and the difficulty of keeping expansion-joints in working order. A further objection to the use of steam-engines underground arises from the inconvenience of taking steam any great distance from the shaft-bottom owing to the radiation of heat and leakage from pipes, and disintegration of the roof shale—moisture and heat being most fruitful sources of damage to the roof and sides of underground roads. Taking into consideration the disadvantages of using steam directly underground, either with underground boilers and engines or by conveying steam from the surface, the policy of adopting such a plan requires very grave consideration before designing or laying out extensive new works.

* *Trans. Fed. Inst.*, vol. iv., page 154. † *Ibid.*, vol. iii., page 158.

‡ *Trans.* [illegible] and 81.

Compressed Air.

Unquestionably compressed air is a convenient form by which to transmit power from the surface for underground haulage, for pumping, working heading-machines, drilling holes for blasting, and for driving coal-cutting machines, and with its convenience may be combined safety in using and freedom from damage to the roads by heat or leakage referred to in the remarks on steam. Compressed air has been more or less in use for underground work for many years, but in its early history imperfections in the engines and machinery used for compressing the air rendered its use costly, the useful effect in some cases not exceeding 20 to 25 per cent. of the power employed. About the year 1850 compressed air was employed near Wigan in working a coal-cutting machine, but as the expectations of the designer were not realized, the air compressing engine was applied to hauling purposes, and did good work in drawing coal up an incline of moderate gradient by means of an endless-chain, but the working of the valves was occasionally impeded, as is still sometimes the case, by the formation of ice in the exhaust pipe; but the chief drawback was the small useful effect obtained from the steam used in compressing the air. Since then great improvement has been made in the construction of both air-compressors and motors, so that at the present time a fairly satisfactory result may be obtained from this mode of transmitting power for underground operations. It would be impossible, if not out of place, in a paper of this character to attempt to go into any lengthy descriptive details of air-compressing machinery, and it probably will be found sufficient to refer to some of the many valuable articles on the subject to be found in the *Transactions*. Papers by Mr. John Sturgeon* and by the late Mr. Joseph Tims should be referred to for practical and useful information.†

The principal point to be observed in the use of compressed air is that the outlet-valves and pipes for conveying the compressed air should be of sufficient capacity, for if too small the friction of the air when being expelled from the cylinder is much increased with a proportionately increased expenditure of power, and is productive of a corresponding elevation of temperature, which is to be deprecated and avoided as much as possible. One of the difficulties met with in the use of air-motors is the formation of ice at the exhaust-valve of the motor, arising from the intense cold produced by the expansion of air freezing the moisture

* *Trans. North Staffs. Inst.*, vol. ix., pages 45 and 321; and *Trans. Chesterfield Inst.*, vol. viii., page 290.

† *Trans. Chesterfield Inst.*, vol. ix., page 149.

contained in the air. It would be interesting to consider how far this may be prevented, or at any rate lessened, by passing the air through some drying medium before it enters the compressing-cylinder. Mr. Tims suggested the introduction into the motor cylinder of a gas which in contact with water would be dissolved and render sensible a large amount of latent heat.

As compared with steam, compressed air is much better adapted for transmitting power over considerable distances underground, but this probably has its limits, looking at the increase in the size of pipes necessary to carry the air extremely long distances and the extra power which must be applied to the compressor to attain the required pressure.

There is one other advantage to be referred to in using air for transmitting power as compared with steam, viz., the exhaust air from the motors, which has the effect of cooling the air-current and adding a little to its volume, whereas steam has the opposite effect on the temperature, and requires special means to be adopted for its disposal.

Electricity.

The use of electricity for the transmission of power has certainly not by any means attained its fullest development, but during the past four or five years its use for colliery purposes has received an impetus, and there is no doubt it will become in a short time the medium *par excellence* for the transmission of power over long distances underground for a variety of purposes, *i.e.*, hauling at distant stations where the main haulage worked from the surface or engine at the bottom of the shaft is not conveniently applicable, pumping water from the bottom of dip galleries under similar circumstances, actuating drilling and coal-cutting machines. In addition to its value as a means of transmitting power, the advantage of obtaining superior lighting on the surface and on main roads underground must be mentioned, and most likely electricity will furnish in the near future a portable and safe light for the working collier at his place of work.

The advantages of an electric power-system under the conditions mentioned, *i.e.*, for districts not easily accessible to direct steam-power or compressed air-motor, may be summarized shortly as follows:—A reduction in capital expenditure as compared with other systems; facility in placing conducting-cables in shafts and in laying them underground to distant motors; small loss from resistance in cable or leakage of current to the earth, compared with the loss in a compressed air system; lowness of cost of maintenance; and speed with which an electric plant can be erected and set to work.

As is the case in all applications of mechanical arrangements, there are some objections to be considered. There is the question of sparking at the motor, from which some danger might be apprehended in a fiery mine. This difficulty is said to be quite overcome by the adoption of the Stokes and Davis enclosed motor. The breakage of a cable and the sparking therefrom is another contingency to be considered. Although the advantages here set forth are considerable, it would be doubtful policy to adopt an electric power-system where steam could be used direct from the surface for haulage purposes; but there does not appear to be the least doubt of the value of electric motors in situations not suitable for mechanical power.

COMBUSTION OF PETROLEUM.

The Priestman oil-engine is one of the latest proposals for applying mechanical power underground, and would, no doubt, be found useful where an engine was required a considerable distance from the shaft, and for some special purpose, and when the installation of an electric system or other motive power was not convenient or desirable at the time when the emergency arose. The principle of the engine is to inject into the cylinder the vapour of petroleum with a sufficient volume of atmospheric air for the combustion of the vapour, this mixture of air and vapour is then ignited by the electric spark from an ordinary bichromate of potash cell with induction-coil. The chief difficulties associated with this engine in underground work are :—The necessity of using a lamp to vaporize the oil on starting the engine at the commencement of work, which would render the use of this form of engine inadmissible in a fiery mine where safety-lamps are exclusively used. The products of combustion, chiefly nitrogen and carbon dioxide, are such that unless a large volume of air is passing through the airway, so that they can be carried away direct to the upcast shaft, there would be considerable danger to life from the deadly nature of the gases evolved. In addition to these difficulties great caution is necessary and strict attention to the special rules under which the petroleum is conveyed and supplied to the engine. Another point to be noticed is that for the proper working and complete combustion of the petroleum vapour constant movement is necessary, intermittent working not being suitable or economical.

The establishment of mining institutes has done much to disseminate valuable information on most subjects useful to mining engineers, and the experience to be gained from the eminently practical papers on haulage make them most worthy of great consideration, indeed they much exceed

in value such general remarks as are contained in this paper. Amongst other papers special attention may be called to those by Messrs. Henry Fisher* and W. G. Phillips.† The colliery manager has the choice of endless-rope, main-and-tail-rope, or simple tail-rope (where the dip roads are of sufficient gradient to take down the rope with the empty waggons). Each form of underground haulage has its advantages according to varying circumstances, and each its admirers and advocates, but speaking generally the endless-rope with the slow movement and steady flow of traffic appears to be in greater favour than other systems. It is probable that in this district with its great variety of inclination of the seams, nature of roof and floor, and other circumstances, difficulties are present which do not occur to those engaged in more favoured districts; calling for greater caution and consideration before being committed to any large outlay on any system.

There are several questions which appear to be well worthy of discussion: among others the point may be raised whether, in the case of a seam dipping at a considerable angle and supposing that an endless-rope would be advantageous on the level ways, it would be judicious and economical to construct the dip-roads at such an angle to the full dip of the seam as to render the endless-rope system available throughout. It may be noted that there are numerous examples of endless-ropes working in a satisfactory manner on gradients of rather high angles. A further point is to what extent it is possible to apply endless-ropes to main self-acting inclines or jigs by which a saving may be effected, through lessened damage to roads and waggons. It would be interesting also to consider the question of taking a main driving-rope from the hauling engine at the surface to the pit-bottom, and from there distributing the power by subsidiary branch lines, or using one long rope over a considerable distance and area of workings.

No doubt this paper will be considered by many to be going again over a too well-beaten track, but the object in taking up the subject and preparing this paper has been to stimulate fair criticism and friendly discussion on one or all of the sections into which it has been divided.

Mr. W. N. Atkinson asked Mr. Wynne whether he had considered the use of compressed air in locomotive engines for underground haulage—a system which was in use in certain mines at the present time?

* *Trans. Chesterfield Inst.*, vol. xii., page 123.
† *Trans. Fed. Inst.*, vol. iii., page 847.

Mr. Wynne said he had read descriptions of the Lishman and Young locomotive, but he was not able to speak as to its value or otherwise.

Mr. W. N. Atkinson said that it might be a good system to adopt for haulage in some of the levels in North Staffordshire, where, owing to the narrowness or crookedness of the levels, it would be difficult to apply any other form of haulage.

Mr. Wynne remarked that he did not regard crookedness of levels as disadvantageous to rope haulage. He had seen rope haulage passing round exceedingly sharp curves. Mr. H. Lewis, in his paper, described a system of haulage in which some of the curves were very sharp—about 66 feet radius.

Mr. E. B. Wain said he could not agree with Mr. Wynne's remarks as to Mr. H. Lewis' paper and curves of 66 feet radius. He saw Mr. Lewis' system some years ago, and he knew that the roads were some of the best and straightest roads in Nottinghamshire.

Mr. Wynne said he had made a mistake; he was referring to Mr. Fisher's haulage at Clifton colliery.*

Mr. Wain said in one instance there were over 5 miles of rope worked from one engine at Mr. Lewis' colliery. Mr. Wynne did not mention the case of steam taken down the shaft as a direct motor applied to underground engines. Steam taken down a shaft was, no doubt, an extravagant system when carried in pipes over long distances. It had, however, one advantage, and that was the valuable aid to ventilation obtained from the exhaust steam. He was not going to say that it was an economical mode of ventilation; but it was worth consideration how far economy could be jointly secured. He was now ventilating the Whitfield colliery by the use of exhaust steam from underground hauling-engines. Mr. Rigby had a very simple manner of dealing with ice in compressed-air hauling-engines. They were fitted with a double exhaust, and instead of having an exhaust pipe leading from the cylinder, he simply left an open hole, another hole on the opposite side of the valve-chest, and so increased the area of the exhaust port, and by that means prevented the freezing affecting the engine to any serious extent. Although there were electric plants working efficiently, they had not become sufficiently perfect to warrant them in extending the use of electric motors underground for haulage. For pumping or any continuous work electric motors could be used economically if high-tension current was used. He thought that a more simple apparatus would have to be

* *Trans. Chesterfield Inst.*, vol. xii., page 135.

invented and the workmen better educated before they could apply electricity to a great extent. Electric motors certainly could be speedily applied, and he knew of a shallow colliery, 30 or 40 feet deep, which was flooded, and in 3 days an electric pumping-plant was at work, and working very well. There seemed to be a growing feeling in favour of endless-rope haulage with the engine placed upon the surface. He had recently seen an endless-rope haulage so driven working a dip, at a gradient of 47 degs., and a load of over 37 tons on the driving-shaft, the rope being placed below the tubs.

Mr. W. N. ATKINSON considered that underground haulage had not been developed largely in the district, owing chiefly to the irregular and great dip of the seams. He moved a vote of thanks to Mr. Wynne for his paper, and that its further discussion be adjourned.

Mr. JOEL SETTLE, in seconding the vote of thanks, observed that there were various matters in relation to underground haulage worthy of consideration. He had seen engines placed at the bottom of the pit, and a great advantage arose where the takers-off and the hookers-on could see what was going on. It would be a retrograde step to place the boilers underground. He was in favour of the extended use of compressed air engines, which could be taken anywhere without risk or danger.

The motion was agreed to.

The following paper by Mr. E. B. Wain was then read on "Stoppings on Underground Roads":—

STOPPINGS ON UNDERGROUND ROADS.

By E. B. WAIN.

A few years ago, on re-opening workings closed by explosion and fire, and subsequently flooded, the writer had some exceptional experiences in building stoppings, and a description of some of the difficulties which were experienced may prove of interest to the members.

Certain portions of the workings above the level of the water by which they had been flooded, showed indications of abnormal heat, and as very large areas of old goafs to the rise, full of fire-damp, were directly connected with the heated portion of the mine, it became necessary for the safety of the future workings that the dangerous portions should be isolated by means of 17 effectual stoppings in the roads connecting them with the area of coal which had to be opened out and worked.

It was laid down as a general condition, that the stoppings should be perfectly airtight, and that in each case there should be two well and substantially built walls at least 3 feet thick, 6 feet apart, and that the intervening space should be filled with dry sand, well rammed.

In order to guard against the remote possibility of an explosion in the rise workings it was also considered necessary, that the walls should be built so as to present a convex surface to the rise workings, that they should be let into the sides of the coal at least 2 feet, and that both roof and floor should be excavated until sound and solid ground was reached.

These conditions were strictly adhered to, but in several cases it was found that the shattering effect of the explosion and the subsequent disintegrating action of the water, had so affected the roof strata in the roads, that the work required to excavate for and build the stoppings was very heavy.

The coal-seam in which the work was done was about 7 feet 6 inches thick, and lying at an inclination of 20 degs. from the horizontal.

In those roads which were standing open or where only a slight thickness of roof had fallen, stoppings were built as shown in Figs. 1 and 2, Plate XVII. All loose coal and dirt was carefully removed, the ground levelled, and the floor and sides cut out to a depth of at least

2 feet. It was considered desirable to build the back wall straight in each case, so as to offer as much resistance as possible to any pressure there might be from the coal sides. The front wall was always curved, as shown on the plan, and the ends skewed so as to resist internal pressure if necessary.

Very few, however, of the stoppings were so easily built as those already described. Where the roof was fallen, or badly shaken, the strength was increased by increasing the thickness of the walls, or by additional stoppings.

Figs. 3 and 4, Plate XVII., show the stoppings erected in a crut, where the roof and sides were badly shaken. They were very carefully put in, as it was the highest point in the old workings, and consequently the point where the greatest volume and pressure of gas was to be expected. The total width of the walls in this case was 15 feet and the height 20 feet. A temporary timber-stopping of 3 feet chock-pieces, set in mortar, was put in, and 3 feet from this a wall, 3 feet in thickness, was built, the intervening space being carefully packed with dry sand; a further space of 6 feet, filled with sand, was left between, and the last wall was also 3 feet thick.

The work required for this stopping was, however, comparatively small compared with some of the others in the old jig-dips, where the force of the explosion had been most severely felt.

The largest of these was No. 7 in the old travelling dip, and was carried to a height of 33 feet above the coal, and to a depth of 3 feet below the coal, making its total height over 40 feet; it averaged 15 feet in width and was 21 feet wide at the base. The time occupied in excavating and preparing the ground and building the walls was 33 days, working 3 shifts, with 10 to 12 men in each shift. This stopping contained over 100,000 bricks, 150 tons of sand, and over 1,200 tons of *dèbris* had to be removed before it could be built.

As the stopping had to be built in an old dip, which was broken down to a very great height, there was much difficulty in removing the falling roof. After loading *dèbris* for several shifts it was found that very little impression was being made, for, as fast as the dirt was loaded out at the foot of the fall, the mass of *dèbris* above kept slipping down. It was then decided to work on the deep side until a solid roof was found, and afterward drive up on the top of the fall until the site of the proposed stopping was reached, the broken material being then taken out, commencing at the top, and the hole secured by timbering as the ground was cleared. Fig. 5, Plate XVIII., shows how this was done.

The road driven up bank was well secured with timber, and all loose dirt pulled off to the solid roof and side as it was made. When the point A was reached, sufficient ground was bared to allow a strong bar to be placed across the face of the dirt and 3 feet below the top. Piles (made of split 7 inches prop-wood) were then driven into the loose dirt for a length of about 4 feet, a layer of dirt 3 feet thick was removed, and another crossbar fixed. This process was repeated until the floor was reached, care being taken to remove all loose and broken material from the sides and to stamp all stretchers well into the solid. The stretcher-bars were strengthened at intervals with horizontal cocker-props set from the sides to the centre of the crossbar, and with short props set from bar to bar. When the dirt was removed and the foundations prepared the building was proceeded with, the side-cuttings for the skewback-ends being only cut out 3 feet above the brickwork as it advanced, so as not to set the stretchers at liberty.

The time occupied was as follows:—Getting dirt out of dip, timbering and dressing sides up ready for building, 36 shifts; building first stopping-wall, 24 shifts; building second stopping-wall and filling in sand, 39 shifts.

No excessive temperature was noted whilst the work was in progress, but an 1½ inches iron pipe was built in the stopping for the purpose of future observations.

This was the largest and most difficult of the stoppings to build, all the others being less, both in height and width.

There was one of the others, however, which was put in under somewhat peculiar circumstances, and a description may be interesting. On account of the suspicious circumstances attending the work, trial boreholes were in every case put through, before entering any road, for the purpose of testing the temperature. In order to guard against a circulation of air fanning up any dormant heat, in no case was more than one opening connected with the old workings, until that portion of the working through which the air was to pass had been explored and made safe. In the case of No. 6 stopping, the trial boreholes showed a normal temperature, but shortly after the first of the two exploring-levels was cut through into the old dip a temperature of 92 degs. Fahr. was noted. The cutting was at once filled with sand for a length of 8 feet, and a pipe for temperature observations left through the sand. The lower exploring-level 25 feet to the deep was then driven forward, and a 12 feet borehole put through, no unusual temperature being noticed, the thermometer registering 66 degs. Fahr. This road was driven forward

to within 6 feet of the old works, and filled with sand for 6 feet back from the face of the coal. The next day an increase in temperature was noted at the No. 7 stopping (travelling dip) which was about 50 yards outbye (see Fig. 8, Plate XVIII.). This had been about the normal temperature of the mine, 70 degs. Fahr., but was found to have risen to 94 degs. No unusual heat was noted at any of the stoppings previously built.

Certain works necessary for the strengthening of the stoppings already built were carried out, which occupied about ten days. Water-pipes from the garland-curbs with a pressure of about 50 lbs. to the square inch were carried up to the point where it was proposed to break into the old road. In the meantime the temperature at the pipes in the exploring-levels was carefully watched, and found to be increasing in the upper level, normal in the lower: a flank hole bored above the upper level giving a temperature of 110 degs. Fahr., with steamy vapour and strong gob stink.

As soon as all the necessary preparations were completed, a careful examination was made of the temperature at all the stoppings, and it was found to be normal—except at the travelling dip, which stood at 95 degs. Fahr.

In order to test if there was any connexion between this and the heat in the old road, and if there was a circulation of air, all men were withdrawn from the workings for 24 hours, and the pipe at the stopping at the highest level was left open (point B., Fig. 8, Plate XVIII.). At the end of that time it was found that the gas was coming off freely, but was quite cool. At the same time the temperature was maintained in the old road. This was considered to be a proof that the high temperature was purely local.

A further heading 4 feet square was driven 10 yards above the upper exploring-level, a borehole put through (Fig. 9, Plate XVIII.), and the temperature was found to be 80 degs. Fahr., the temperatures at the two holes in the upper exploring-levels being 110 and 95 degs. and in the lower level 65 degs. Fahr. (The boreholes were kept carefully plugged so as to prevent any circulation of air). This was a further proof that the heat was local, and a road was at once cut through into the old dip with the upper exploring-level, a carefully fitted air-door having been previously fixed (Fig. 9) to act as a temporary stopping in case it was necessary to cut off the air from the dip on account of any dangerous or sudden increase in the temperature.

A great volume of steamy vapour mixed with gas was given off as soon as the road was thurled, and the temperature was maintained, but did not increase.

The roof was found to have only fallen to a height of about 6 feet above the coal. At a point 7 yards above the thurling, the roof was found to be standing, and a heap of soot and small coal which had been washed down against the fall when the pit was flooded was quite moist and heating. This was removed, a temporary stopping was put in, and the stopping completed, as shown in Figs. 10 and 11 (Plate XVIII.).

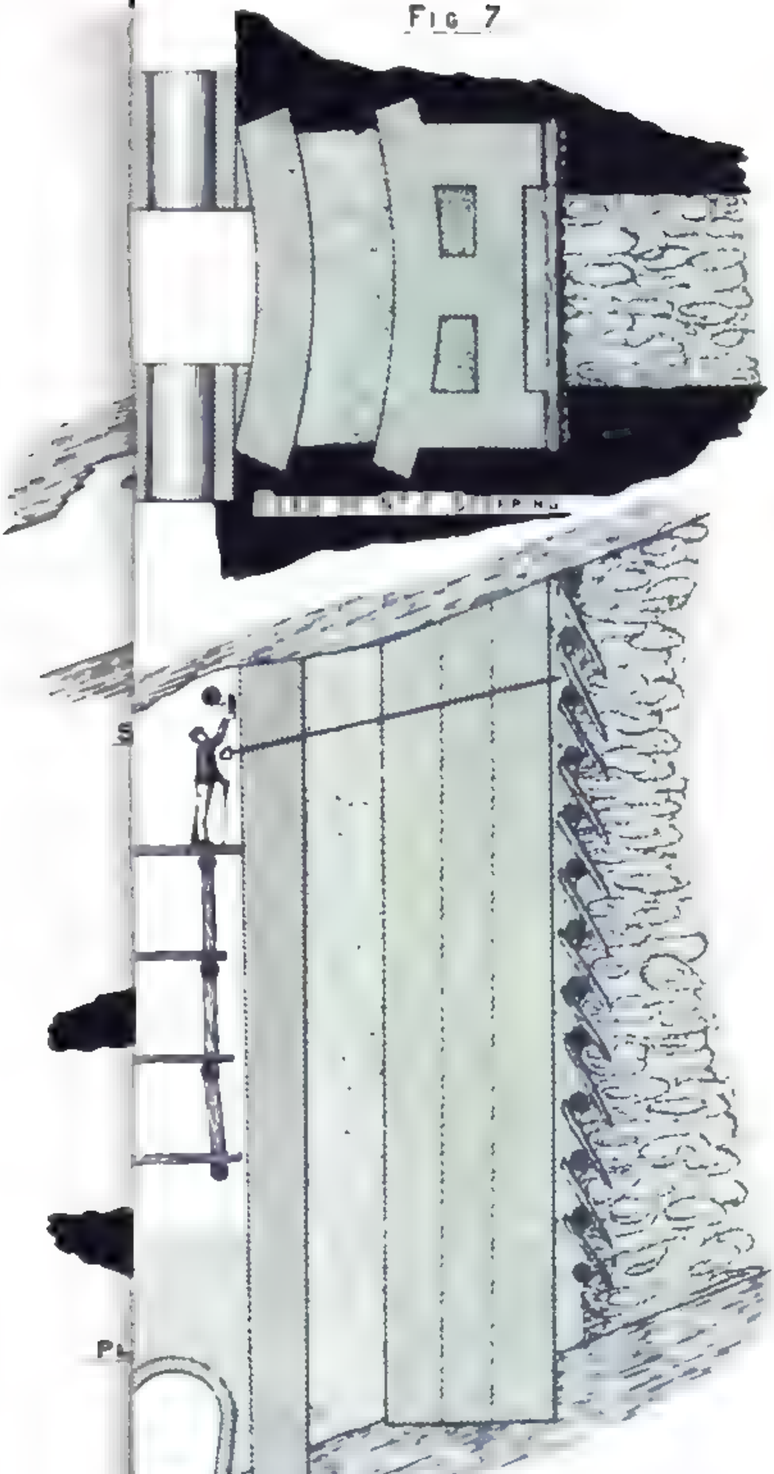
It may appear that in this case unusual precautions were taken in dealing with the matter; but it must be remembered that above, and in direct communication with the road where the heat was observed, were many acres of old workings charged to their utmost capacity with fire-damp; and that if a gob-fire had broken out, the pit would have been wrecked, and every man present at the time would certainly have lost his life.

The whole of the stoppings and the necessary headings were completed in August, 1887, and up to the present time they are standing as well as on the day they were finished. The largest of the stoppings (No. 7) was completed in November, 1886, and after seven years is in perfect order, the plastering on the front wall being uncracked. There is some pressure of gas (about $\frac{1}{4}$ inch of water) on the stoppings, but their gas-tightness is proved by the fact that in no case is gas escaping from the old workings except by the pipes which were left through the walls to prevent the production of any excessive pressure. These pipes are each fitted with a simple back-pressure valve (Fig. 12, Plate XVIII.), which is constructed so as to prevent any circulation of air taking place.

In conclusion, it only remains to say that the successful manner in which the peculiarly difficult operations described were carried out was especially due to the care and attention with which the workmen employed performed their duties, and the greatest credit is due to them for the steady determination with which they worked in face of great and exceptional difficulty and danger. There can be no greater proof of this than is shown by the fact that during the thirteen months' continuous work required to complete the stoppings there was not a single accident resulting in serious bodily injury to any person employed.

Mr. J. R. Haines said the work which Mr. Wain had described was one of great magnitude, especially in the making of No. 7 stopping. They must thank Mr. Wain for having brought the matter before them.

Fig 7



Section of No 7 Stopping

Col. Strick said he had great pleasure in seconding the motion. He enquired whether the work described was on the occasion of the re-opening of the Whitfield colliery?

Mr. Wain replied that it was.

Col. Strick said, looking at the magnitude of the work, it was an arduous, costly, and dangerous undertaking, reflecting great credit on the management, especially as it had been carried out without accident.

The vote was adopted.

DISCUSSION UPON MR. W. N. ATKINSON'S PAPER ON "THE USE OF PETROLEUM, PARAFFIN, AND OTHER MINERAL OILS UNDERGROUND."*

Mr. W. N. Atkinson said he was glad to observe that the use of flaming torchlights had been abolished at many collieries, and he hoped that those used would soon be abandoned altogether. They were one of the most frequent causes of fire underground. There was another matter to which his attention had been drawn recently, that was the heating of wooden brakes used on jigwheels. He had heard of those having taken fire or given off smoke, but he had never seen a case himself. It should be understood that such an occurrence was a source of danger, and should not be passed over as a matter of course. It was possible that the attendant might leave the brake at the end of the shift just on the point of taking fire, and the result might be most disastrous.

Mr. Joel Settle remarked that he always used hemp-rope on the brakes belowground, and that they had never taken fire.

Mr. Wain asked whether a flat hemp-rope would not be more inflammable than the wooden brake?

Mr. Settle thought it would not give the same friction.

Mr. Atkinson said he had seen a hemp-rope, which had been used as a brake, very much charred.

Mr. Hassam stated that he had tried both hemp and wood on the brakes of winding-engines, and hemp did not char or take fire so rapidly as wood.

Mr. T. V. Hughes thought that some means could be adopted for absorbing the heat as soon as it was generated.

* *Trans. Fed. Inst.*, vol. v., page 434.

Mr. E. B. Wain said he could show several cwts. of hemp rope which, if not fired, had been charred. He believed that an iron bar was the best material for a brake.

Col. Strick remarked that an iron brake would produce sparks.

Mr. J. R. Haines said he had used hemp-rope on brakes for twenty years and it had never taken fire, but from what had been stated by several members it appeared that it might do so. He thought that the heating of wooden or hemp-rope brakes might be prevented, or at least reduced, if the brake rims were turned up true.

The discussion then closed.

APPENDIX.

I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF FOREIGN SOCIETIES AND FOREIGN PUBLICATIONS.

THE ANTIMONY MINE OF FREYCENET, UPPER LOIRE, FRANCE.

La Mine d'Antimoine de Freycenet. By P. L. Burthe. *Annales des Mines,* 1893, *series* 9, *vol. iv., pages* 15-33.

The mining concession of Freycenet, covering an area of 570 acres, is situated 3¾ miles west of the little market-town of Lavoute-Chilhac. Within the concession the so-called plateau de Freycenet and plateau de Mont Rome are divided by the deep ravine of La Rhode from the broad plateau of the same name. West of this ravine the rocks are gneiss, east of it they are mica-schists. The gneiss is very felspathic, soft, more massive, and more regularly-bedded than the mica-schists; it appears to strike east-and-west. The mica-schists are very variable and thinly bedded, with a steep dip; their east-and-west strike on the plateau de Freycenet suddenly changes to a north-and-south strike on the plateau de Mont Rome. They are frequently faulted, but the faulting does not seem to extend much in depth. There are two varieties of mica-schists here which seem to have been unfavourable to the formation of metalliferous veins: a hard, reddish-white, very felspathic, slightly micaceous rock, and an extremely soft schist, almost entirely made up of flakes of bronze-coloured mica. A few veins of granulite are met with, but do not appear to have had any influence on the occurrence of the metalliferous veins, and the same statement applies to the lumps of green hornblendic rock occasionally found in contact with the antimony ore.

There are seven antimony-bearing veins (these alone are worked), three holding complex antimony-lead and argentiferous ores, and one of argentiferous galena. The antimony ore is a very pure sulphide, slightly altered here and there at the outcrop to a white or yellow oxide. The veins are either filled up with the country schist, or with a very compact bluish quartz, spangled with fine needles of stibnite when the vein is poor, and disappearing almost entirely as the vein becomes richer. Iron pyrites is not particularly abundant; pink or white calcite sometimes occurs, and there are traces of zinc blende, but no lead or arsenic; nor are the antimony veins ever found to be auriferous or argentiferous. The rich portions of a vein form little masses of practically pure ore, separated from one another by lengths very poor in ore or entirely barren. In this connexion veins No. 1 and No. 2 of the plateau de Freycenet are typical. They strike east-and-west; No. 1 for 196 feet in horizontal length has been worked uninterruptedly to a depth of 164 feet, and in No. 2 for 206 feet in horizontal length has been worked to a depth of 321 feet.

Desultory efforts were made to work the mine until it was re-opened, new shafts and adits being driven by its present owners. The production from the two veins just mentiond in nineteen months from June, 1889, to December, 1890, amounted to close upon 638 tons of marketable ore, which, being sold at the average price of £9 3s. 10d. per ton, yielded a gross profit of £2 10s. 9d. per ton.

The nature of the ores and the conditions of their occurrence as described for the Freycenet mining concession are repeated in similar concessions along the left bank of the Allier (Barlet, Chazelles, Lubilhac), and in other localities for which there is at present no concessions, but where old heaps of loose *débris* testify to the existence in bygone days of a far more extensive mining industry in that district. O. S. E.

THE ANALYSIS OF COAL.

Technische Analysen und Proben aus dem chemischen Laboratorium der k.k. geologischen Reichsanstalt. *By* C. VON JOHN *and* H. B. VON FOULLON. *Jahrbuch der k.k. geologischen Reichsanstalt, Vienna,* 1892, *vol. xlii., pages* 155-178.

The authors, in communicating determinations of the water, ash, and sulphur-content, and of the calorific power of coals from various formations and localities in the Austro-Hungarian empire, draw attention to the untrustworthiness of the Berthier method of determination. They state that by this method, with coals rich in hydrogen, the figures for the calorific power always come out too small. The report also contains chemical analyses of various Austro-Hungarian coals, cokes, patent fuel, and of an anthracite found at Orsilia, near Genoa (carbon 72·46 per cent. and ash 21·5 per cent.). O. S. E.

THE MANUFACTURE COLLIERY EXPLOSION, FRANCE.

L'Explosion de Grisou survenue au Puits de la Manufacture (Loire), le 6 *Décembre,* 1891. ANON. *Annales des Mines,* 1893, *series* 9, *vol. iv., pages* 235-251.

An explosion of fire-damp occurred at the Manufacture colliery, Loire, France, on December 6th, 1891, and resulted in the death of 62 persons, and in severe injury to 10 others. The explosion is attributed to the temporary stoppage of the ventilator on the morning of December 6th. During this stoppage inflammable gases escaped from old workings, and when the fan was restarted these gases (becoming mixed with fresh air) formed an explosive mixture. The mine was on fire, and one of the stoppings having become reduced in thickness in its upper part to a few inches the explosive mixture passed through and was ignited at the fire.

This accident illustrates the importance of isolating the working parts of the mine from old workings, and shows that the ventilating currents traversing old workings should be completely isolated from those passing through the working-places. It further proves that it is impossible to rely upon the efficiency of stoppings, and shows the necessity of passing a current of fresh air along them, in the case of a mine subject to spontaneous combustion. O. S. E.

THE HARDY FIRE-DAMP DECTECTOR.

Sur l'application des vibrations sonores à l'analyse des mélanges de deux gaz de densités différentes. *By* E. HARDY. *Comptes-Rendus hebdomadaires des Séances de l'Académie des Sciences,* 1893, *vol. cxvii., pages* 573-574.

When two organ-pipes, giving the same note, are sounded together by the aid of two distinct organ-bellows, filled with fresh air, a single note is obtained. If, however, one of the bellows, instead of being supplied with pure air, is supplied with a mixture of air and some other gas, the note of the organ-pipe is correspondingly modified, and the two pipes sounding together give more or less frequent beats according as the air is mixed more or less with the other gas.

The Hardy fire-damp detector consists of two separate bellows and two organ-pipes. One of the bellows and its organ-pipe are enclosed in an airtight case containing pure air; the other is supplied from the gaseous mixture. Each experiment is very short, and occupies only a few seconds. The organ-pipes sounding ut_4, and the gas mixed being marsh gas, the following results are obtained :—

For	1	per cent.	of marsh gas in air	there is about	1	beat	per	3	seconds.
,,	2	,,	,,	,,	3	,,		2	,,
,,	3	,,	,,	,,	2	,,		1	,,
,,	4	,,	,,	,,	3	,,		1	,,

And so on, the beats increasing in frequency in proportion as the gaseous mixture contains more marsh gas. When there is 12 per cent., there are about 9 beats per second; with 20 per cent. they become very rapid, and with 25 per cent., extremely rapid, but always very distinct and clear.

The Hardy fire-damp detector gives similar results in mixtures of air and carbonic acid gas. In a few hours the respiration of a single person adds sufficient carbonic acid gas to the air of a room for the gas-detector to indicate its presence.

Instruments intended for testing gaseous mixtures whose density is almost the same as pure air, should be fitted with an organ-pipe giving a higher note; ut_5, for instance.

This fire-damp detector is especially intended for the testing of the presence of fire-damp in mines, may take any form, and will afford continuous indications, not only in the mine, but also in the office of the mining engineer. M. W. B.

THE CHESNEAU FIRE-DAMP INDICATOR.

(1) *Essais effectués dans les Mines avec l'Indicateur de Grisou de G. Chesneau. By* G. Chesneau. *Annales des Mines*, 1893, *series* 9, *vol. iii., pages* 509-531.

(2) *Instruction pour l'emploi de l'Indicateur de Grisou de G. Chesneau.* Idem. *Annales des Mines*, 1893, *series* 9, *vol. iii., pages* 532-544, *and figures.*

The Chesneau fire-damp indicator has already been described in the *Transactions.**

The first paper is a report submitted to the French Fire-damp Commission, and recounts the results of experiments made with fifteen of the Chesneau lamps in fiery mines of the various coal-fields of France. Check experiments were conducted at the Paris School of Mines, and in the laboratories of the St. Etienne and Ronchamp collieries companies, the total number of comparisons made amounting to 200. Generally speaking, the results proved so satisfactory that several colliery managers proceeded to use the indicator in their fiery pits, without waiting for any official decision as to their value, and the chief engineer of the Anzin collieries announced his intention of substituting the Chesneau indicator for the Pieler lamp.

The author sums up the improvements which he has made in this fire-damp indicator, and he draws special attention to the use of cotton-wadding in the spirit reservoir. When the copper chloride solution (mixed with the methylated spirit) comes into contact with the metallic copper wall of the reservoir, an insoluble sub-chloride tends to separate out, clogs the wick, and arrests the ascension of the alcohol, so that the burning wick carbonizes and the flame-caps rapidly grow dim; the wadding absorbs the sub-chloride and obviates all these inconveniences. The alcohol should be of constant specific gravity of 0·8275 at 60 degs. Fahr.

That the Chesneau lamp is extinguished immediately in explosive mixtures has been proved repeatedly, and the author states that a Government engineer took it about with him for 4 hours (in workings where no one would have dared to take a Pieler lamp) in atmospheres containing 2 to 4 per cent. of fire-damp, without its becoming noticeably heated or its regulation being disturbed. As to the clearness of the flame-caps with less than 1 per cent. of fire-damp, the Chesneau indicator has been on several occasions experimentally compared with the Pieler lamp, much

* *Trans. Fed. Inst.*, vol. iv., page 617.

to the disadvantage of the latter. The indications given by the Chesneau indicator agree, on the whole, very closely with the laboratory analyses of the pit air made to check the experiments; and it has never, even in dusty mines, indicated fire-damp when the analyses showed that none was present. All tends to prove that the lamp, in addition to being a good indicator, is equivalent to a good safety-lamp. and can be confidently used in any part of a mine. O. S. E.

THE BORINGS FOR NATURAL GAS IN THE TERTIARY STRATA OF UPPER AUSTRIA.

Neue Tiefbohrungen auf brennbare Gase im Schlier von Wels, Grieskirchen und Eferding in Oberösterreich. By G. A. Koch. *Verhandlungen der k.k. geologischen Reichsanstalt, Vienna,* 1893, *vol. v., pages* 101-129.

The Schlier formation is defined by Ritter Von Hauer as consisting of marls and sands with few organic remains; it is of Neogene age, probably late Miocene. The present paper is in continuation of a report published by the author in 1892. Within the municipal boundaries of the town of Wels no less than 16 borings had been put down by Easter, 1893, and the author gives detailed notes on each. Taking them in the order in which they are enumerated by him, we have :—

No. 1.—Depth, 820 feet. The average yield of gas is estimated at 5,300 cubic feet per 24 hours, but as a great deal is lost through defective appliances, it is believed that the real amount is nearer 7,000 cubic feet. The yield is larger with a low than with a high barometer. Although this is surrounded by new borings, the gas comes off in apparently undiminished quantity; it is used for light and fuel. Water is squirted out of the shaft by the gas-pressure.

No. 2.—Depth, 880 feet. Yield too small for industrial purposes. Brackish water abundant.

No. 3.—Depth, 558 feet. Yields a good deal more gas than the former; the two, put together, are stated by the landowner to yield between 353 and 530 cubic feet of gas per day. The gas is chiefly used for heating purposes.

No. 4.—Depth, 886 feet. Gas in moderate quantity. Water comes up by bursts; it contains, among other alkalies, magnesia and ammonia. The gas, colourless, odourless, and combustible, was analysed, with the following result by volume :—Carbon dioxide, 0·7; oxygen, 1·9; nitrogen, 16·5; methane, 79·7; and carbon monoxide, 1·2. Its heating power is somewhat greater than its illuminating power, but the latter is much improved by the admixture of a very small quantity of coal-gas. It is used for light and fuel.

No. 5.—Boring put down by the municipality in the public gardens. Depth, 677 feet. When the boring had reached 374 feet, a curious crackling sound gave warning of the uprush of gas, and gas continued to come off down to 656 feet. On account of the breakage of rods and the striking of hard strata the operation of boring has been temporarily suspended. (The strata of the Schlier become harder as one approaches the Traun river, near which this bore-hole is situated.)

No. 6.—Depth, 590½ feet. Gas-yield abundant. It is used for heating and lighting the owner's residence.

No. 7.—Boring stopped at a depth of 689 feet. Gas comes off slowly.

No. 8.—At Wels Castle a boring was carried down 984 feet. At 505 feet gas began to come off, spirting up water before it.

No. 9.—Boring stopped at a depth of 640 feet. Odourless gas came off in large quantities. It is used for heating purposes.

Nos. 10 and 11.—In the garden of the Catholic Working Men's Club. The first boring went on satisfactorily till a depth of 292 feet was reached, when the tool

struck a lump of quartz and snapped. The next boring is closely adjacent, and attains a depth of 512 feet. A doubtful estimate puts the gas-yield at 565 cubic feet daily.

No. 12.—Depth, 551 feet. Gas distributed in twelve burners by pipes about ½ inch internal diameter, burns day and night, giving sufficient illumination for the underground (basement) portions of a cement factory.

No. 13.—Depth, 394 feet. Plenty of gas, but no water.

No. 14.—Depth, 697 feet. The gas-yield was said to be double that of No. 1 well, *i.e.*, 10,594 cubic feet per day at least.

No. 15.—Gas was first met with at 171 feet.

No. 16.—Gas met with at 196 feet, boring carried beyond 370 feet. No water. Gas partly used for firing boilers at a steam saw-mill.

So much for the results obtained at Wels, but the boring fever has taken possession of the people in other districts of Upper Austria, which lie upon the same geological formation, and the following trials are reported:—At Willing, parish of Neukirchen-Lambach, a boring went down 656 feet without striking gas-bearing strata. At Haiding gas was found at a depth of 230 feet, but the boring apparatus was so clumsily handled that operations will have to be started afresh. At Grieskirchen, north-west of Wels, the Schlier formation all but crops out at the surface, and a boring put down there in March, 1893, attained a depth of 918 feet. Combustible gases came off in considerable quantity; within the last 32 feet a bituminous stratum about 20 feet thick was pierced through. No trace of petroleum was found, although the borehole is not ¼ mile distant from a so-called petroleum spring. At Simbach and Lahöfen artesian wells have yielded water reeking with sulphuretted hydrogen.

The few analyses that have been made of waters from the Schlier point to the occurrence in some cases of bromides and iodides, together with sodium chloride, and the author suggests that the strata are of marine origin. In his general summary he points out that, taken as a whole, the gas-yield is abundant, nor does it appear to diminish with time. Bearing in mind the great thickness of the Schlier formation, and the vast horizontal extent of the gas-bearing strata in Upper Austria, as also the relatively insignificant number of borings, there is no reason to apprehend exhaustion of the natural gas-reservoirs for many years. Whenever that exhaustion does take place, the American example may well be followed by searching deeper down for other gas-bearing strata.

It will be seen that gas is already tapped at very different depths in the Schlier, from 115 down to 820 feet and beyond. Within the Wels municipal boundary three distinct gas-bearing zones may be recognized: (1) a southern zone, parallel with the Traun river, poor in gas; (2) a zone parallel to the first, not so poor; (3) the Town Moor zone, much the richest in gas of the three. It is considered extremely probable by Dr. Koch that petroleum or ozokerite will ultimately be discovered in paying quantities in these districts. O. S. E.

ANCIENT GOLD-MINES IN BOSNIA.

Ueber Goldgewinnungs-stätten der Alten in Bosnien. *By* H. B. VON FOULLON. *Jahrbuch der k.k. geologischen Reichsanstalt, Vienna,* 1892, *vol. xlii., pages* 1-52, *with map, plate I., and five figures.*

A short summary of the bibliography of the subject is followed by a geological description of the mountainous district which stretches east of the upper course of the Vrbas river. Generally speaking, the rocks consist of Palæozoic slates and

limestones, unconformably overlain by Triassic beds (Werfen shales), of unfossiliferous fresh water Tertiary strata, masses of eruptive rock, and great spreads of drift and alluvial deposits. The two last-named are of paramount importance in connexion with the occurrence of gold.

The drift varies in character, but is usually a very coarse gravel, largely made up of pebbles of eruptive rock, ironstone, and manganese-nodules. The alluvial deposits, of course, comprise representatives of all the rocks in the district, but, in contradistinction to the drift, the chief components are limestone and slate. It is noted that quartz is of rare occurrence either in the drift or the alluvium, and when it is found, its origin can be traced to certain lenticular masses in the slates.

The eruptive rocks have often a distinctly stratified appearance, the stratification being conformable with that of the Palæozoic slates over which they are spread; and the evidence points to the vicinity of the headwaters of the Suhodol burn as the probable centre of eruption. These rocks are described as quartz-porphyries, more recent than the Palæozoic slates, but older than the limestones.

A detailed account is then given of the abandoned diggings and old waste-heaps, which still bear witness to the mining activity of the ancients, the following topographical subdivision being adopted:—

1.—The diggings in the upper valley of Vrbas.	Vrbas river-basin (upper portion).
2.—The diggings in the higher mountain-region.	
3.—The old workings in the Rosinj district.	

4.—The diggings in the Lasva valley.
5.—The diggings in the Fojnica-Zeleznica valley.
6.—The diggings in the lower mountain region along the Fojnica-Zeleznica.

Local traditions import that gold-mining went on here, more or less interruptedly for over two thousand years, from the days of the Romans to the beginning of the present century. The industry appears, indeed, to have been pre-Roman, the imperial conquerors merely continuing and expanding the work begun by the aborigines. However that may be, the ancients, invariably proceeding in the uphill direction, appear to have systematically washed round about Gornji Vakuf every bit of drift or alluvium that would repay the trouble. They were quite aware of the commercial value of the pockets of drift occurring in clefts, crevices, hollows, or basins; and the testing of samples from the drift-material, wherever it has been left untouched by the ancients, shows it to be extremely poor in gold. Such gold as it does contain is very finely divided, dispersed in the form of minute, excessively thin flakes.

At the old diggings of the Zlatno Gueno (or golden threshing-floor), abutted a water-conduit six miles long, carried round steep mountain-ridges, and a double conduit of the same kind is traced up to the Cervena Zemlja (or loam-heap): the antiquity of this enormous waste-heap may be gauged from the gnarled timber which now clothes its lower slopes. The author infers that labour was cheap in those bygone days, rather than that gold was extraordinarily abundant in the deposits of the Vrbas river-basin. There is no trace of metalliferous veins here, nor of any mining operations such as would have been conducted to work veins.

As to the origin of the gold in the Vrbas river-basin, with a view to the determination of that point, thirty samples from as many different localities were washed and analysed. They all contained red hæmatite, magnetite, titanite, zircon; several contained brown hæmatite, manganese ore, baryta, rutile, tourmaline, etc., and four samples contained cinnabar: only five are mentioned as not containing free gold, in a very finely-divided state. Now, nearly every one of the constituents of these samples are also found in the sand which filled up a limestone-cavern at the Bosanska-Idria mine on the Zec. The limestones which bulk largely in the mountain *massifs* contain quicksilver and fahlores, and the author's theory appears to be that

the gold, in drift and alluvium alike, is transported material resulting from the decomposition and degradation of those rocks, as also from the denudation of the clay-slates, but not from the quartz-porphyries. The ancients evidently expected to find, and possibly did find, some gold in the slates; for they dug pretty deeply into the solid rock in a good many places; and the fact that no old waste-heaps are visible near the depressions thus left, merely shows that the material was taken away to some convenient spot, and stamped and washed there.

The Lasva valley was never so active a gold-washing centre as the Gornj Vakuf (Vrbas river) district; while, concerning the Fojnica-Zeleznica valley, tradition curiously enough dwells on rich silver-mines, for which there is not a shred of evidence, but there are unmistakable traces of mercury and gold-mining having been carried on. O. S. E.

THE GOLD-DEPOSITS OF THE PUNA DE JUJUY, ARGENTINE REPUBLIC.

Los yacimientos auriferos de la Puna de Jujuy. By V. NOVARESE. *Anales de la Sociedad Cientifica Argentina, Buenos Aires,* 1893, *vol. xxxv., pages* 89-117.

The Puna de Jujuy is a region of high, treeless, arid table-land, bounded by mountain-ranges running north and south, parallel with the general trend of the main chain of the Andes. The most ancient rocks of the district are schists and grauwackes, several thousands of feet thick, which contain, the latter especially, pyrites-crystals in great abundance and gold-bearing veins. In this formation no fossils have so far been discovered, but Dr. Brackebusch, reasoning from analogy with similar rocks in neighbouring districts, holds that it is of Silurian age. The schists and grauwackes are succeeded by unfossiliferous, vividly-coloured, red and yellow sands, more or less marly shales, dolomitic limestones of varying structure, and another series of sands, distinguishable from afar by their strikingly varied colouration. These have been grouped together as Lower Cretaceous.

The two groups of strata above described are folded and distorted on a magnificent scale; above them lie almost horizontally Tertiary sands, clays, and micro-conglomerates. These are followed by a coarse conglomerate of Quaternary age, which is gold-bearing; it is made up of fragments of white, grey, and green Silurian quartzite, cemented together by a grey or red argillaceous matrix. This conglomerate runs in great terraces along the mountain-valleys, and forms the fine plateau on which is built the capital of the province, the city of Jujuy. Moreover, gold-bearing alluvia of later age occur, and efflorescences of sodium chloride and various sulphates on the surface-soil are common. In the dry season, when the mountain torrents disappear, their beds are found covered with a saline crust. Ancient lava-flows and porphyritic and trachytic cones are numerous; they are certainly of post-Palæozoic, and probably of Tertiary, or even post-Tertiary age.

The gold-deposits are almost entirely limited to the western portion of the Puna (departments of La Rinconada, Santa Catalina, and part of Cochinoca). Those of the Sierra de Cochinoca await more thorough exploration. The most important known deposits occur in the range which divides the Rio Grande de San Juan de Mayo from the high table-land, the Sierra de Cabalonga or De La Rinconada: this Sierra runs north and south for about 65 miles, and varies in width from 6 to 8 miles.

Auriferous white quartz-veins occur in the schist-grauwacke formation, preferably in the schists. They are numerous, and follow the general strike and dip of

the country rock. The quartz is crypto-crystalline, compact, and as a rule extremely hard; crystals of gold the author failed to see; the native metal invariably appeared in small amorphous agglomerations. One peculiarity is that the gold at times impregnates the country-rock, so that the latter is often richer than the quartz itself. Various more or less desultory attempts have been made to work the veins industrially, but all have been successively abandoned. The author collected some specimens which were assayed at the mint at Buenos Aires, and yielded the following results:—

		Auriferous Quartz. Grammes.	Country Schist. Grammes.	Country Schist excavated and found in the Old Workings. Grammes.
La Perdida mine, Sta. Catalina ...	Gold per ton	15	112·5	64·94
La Cruz del Sud mine, Timon Cruz, headwaters of the Rio Sta. Catalina	"	179·9	5·0	—

From the latter also, a galena, with much quartz-gangue, yielded per ton 217·3 kilogrammes of lead, 235 grammes of silver, and 5 grammes of gold. The small quantity of material collected by the author did not permit of analysis being made of the gold itself, as found in the veins.

The author, following the classification adopted by professional miners, subdivides the gold placer, etc., deposits as follows:—

1. Superficial deposits (*aventaderos* or shallow placers), evidently of Quaternary age; these include (*a*) placers *in loco*, formed by the degradation in place of the vein-material; (*b*) the bottom of the actual valleys and the beds of modern rivers; (*c*) the now abandoned beds of actual rivers in the drift-terraces of their valleys.

2. Deep-seated deposits (*veneros* or deep leads) covered by more or less considerable masses of barren material distinct from the auriferous stratum.

The gold-bearing conglomerate, composed chiefly, as above stated, of pebbles of Silurian grauwacke and schist, is further characterized by cubical crystals of pyrites, locally termed *binches*, the abundance of which is regarded by the miners as an indicator of the richness of the conglomerate (this, however, is not invariably a safe guide), and by the presence of an extremely fine, magnetic black sand which is always found in the washings to accompany the gold. There is an idea prevalent in the district that rubies occur in the auriferous conglomerate, but these turn out to be fragments of rose quartz; the author, has, however, seen crystalline fragments, which appear referable to topaz and garnet. The richest mine in La Puna is that belonging to category *a*, of La Perdida, already mentioned in connexion with the quartz-vein deposits; despite the very imperfect method of washing which there obtains, the daily production in gold nuggets averages 30 grammes per cubic metre of conglomerate—this, without counting the gold-dust, which practically all goes to waste.

In category *b* the gully or Quebrada de Ajedrez and the Quebrada de Llaucana are good examples. Here the conglomerate-gravel is richest near its base; the nuggets show many traces of the action of water, being rounded and sometimes flattened.

In category *c*, the Buena Vista concession, north of the Cerro Galan peak, along the southern course of the Rio Grande de San Juan de Mayo, may be cited. The deposits here yield very pure gold in nuggets and flakes, averaging 3 grammes of gold per cubic metre of material.

Of the deep leads the Eureka mine (14,181 feet above sea-level) at Tagarete, is the sole remaining example in La Puna. The conglomerate here is of great thickness,

and its components attain enormous dimensions, but the auriferous seam is much less coarse, and the cementing-matrix is softer than in the mass of the rock. It is characterized by a roof containing agglomerations of native copper and copper ore, cemented by a vividly-coloured green and blue matrix. This band is as rich in gold as the non-cupriferous band. The average gold production of the Eureka mine is 5 to 6 grammes of rich-coloured nugget gold per cubic metre of conglomerate; the process of washing is very imperfect. A small nugget from this mine was found on analysis to contain gold 95·7 per cent., silver 3·86 per cent., and iron 0·427 per cent. O. S. E.

GEOLOGY OF THE TUNISIAN ATLAS.

Beiträge zur Kenntniss des tunisischen Atlas. By A. BALTZER. *Neues Jahrbuch für Mineralogie, Geologie, und Palæontologie, Stuttgart,* 1893, *vol. ii., pages* 26-41, *and plate III.*

A short description is given of the topography of the mountain-region as distinct from the plain-country of Tunisia, the author dividing the former area as follows:—

1.—Northern zone, forming the continuation of the lesser Atlas, bounded to the north by the Mediterranean and south by the Medjerda river. Here are the Khroumir Hills with fine cork-oak forests, and the Nefzas Hills with metalliferous rocks.

2.— Middle zone, forming the continuation of the great Atlas, with a well-defined Jurassic chain. All the mountain-ranges in this zone run north-east, and are deflected to the north as they approach the plain of Kairouan.

3.—Southern zone, bounded south and west by the depression of the Chotts (salt lakes) and east by the Sahel (a fertile plain).

The entire mountain-region of Tunisia is an area of plication, a folding movement which lasted into Pliocene times; and along a north-and-south line about 200 miles in extent, which may be drawn from Tabarka to the Chotts, the author reckons no less than twenty-five hill-ranges or great folds.

He describes in some detail the Zaghouan chain. Here in the grey, variously coarse and fine-grained, crystalline, massively-bedded limestones of Jurassic age, which form the great mass of the mountains, occur deposits of zinc ore (carbonates and silicates). These ores are associated with galena, blende, baryte, and orthoclase, they have only been worked within the last few years, and the author noted about a dozen *attaques* or diggings, mostly very shallow. The zinc ore is roasted, shipped at Tunis to Antwerp, and forwarded thence for further treatment to La Vieille Montagne. Jurassic limestone with zinc ores and galena also occurs in the Jebel Ressas, north east of the Zaghouan chain, and at the Bou Kournine, near Hammam Lif. The zinc ores occur variously as stratified deposits, infillings of cracks and fissures, concretions, and impregnations. The sections in the plate show the localities where the ores are found, but otherwise this abstract contains almost every particle of information concerning the ores that can be gleaned from the original paper. Mr. Baltzer appears to be more concerned with the tectonic geology, and the comparison of the Tunisian Jurassic with the Swiss, than with matters which more immediately interest the mining engineer. O. S. E.

GEOLOGY OF THE TERRITORY OF NEUQUEN, ARGENTINE REPUBLIC.

Neuquen. *By* FRANCIS ALBERT. *Boletin del Instituto Geográfico Argentino, Buenos Ayres*, 1893, *vol. xiv., pages* 154-176.

Coal-deposits are said to extend over large areas, and where trials have been made the deposits seemed to increase in depth. Two samples analysed, one in Paris and the other at Buenos Ayres, were reported of good quality, ash 2 per cent. Four petroleum-wells are known, and the oil is used by the inhabitants for illuminating purposes. Finds of copper, iron, and silver ores are known, as well as argentiferous galena of so high a grade that a Chilian company found it pay to have the ore carried on mule-back over the mountains into Chili for treatment. Other minerals known to occur abundantly are sodium nitrate, rock-salt, native sulphur, amber, jet, marbles and plastic clays of various kinds. Alluvial gold, yielding sometimes fairly large nuggets, has been found in the sands of at least one stream, and gold-washing is now going on.

Two leagues west of the pastoral park-like district of Los Pinos rises the (moribund) volcano, Mount Copahues, with its sixty or more thermal springs of different chemical composition and varying temperatures. Other thermal springs are known at El Domuyo and Chapún; these have formed great deposits of native sulphur.

The projected Interoceanic Railway from Buenos Ayres harbour to Talcahuano harbour in Chile, would pass through the territories of Pampa Central and Neuquen, crossing the Andes at Antuco. It is stated that the French engineers who made a reconnaissance-survey of this route in 1889-1890, considered that the greatest piece of work, the tunnel under the Andes, need not be more than ⅛ mile long, a statement which certainly appears to require confirmation. O. S. E.

THE GEOLOGY OF NORTHERN PATAGONIA, ARGENTINE REPUBLIC.

Zur Geologie von Nord-Patagonien. *By* JOSEF V. SIEMIRADZKI. *Neues Jahrbuch für Mineralogie, Geologie, und Palæontologie, Stuttgart*, 1893, *vol. i., pages* 22-32.

The author started from Buenos Ayres in November, 1891, in charge of a small exploring party, to examine the comparatively little-known districts inhabited by the Ranqueles and Manzaneros Indians, districts now termed officially Pampa Central, Rio Negro, and Neuquen.

Drawing a section from the mouth of Rio de la Plata west-south-west across the Pampa Central, the first formation met with is the Pampa proper, consisting of the enormous alluvial deposits of the great river Parana. Below these are Pliocene shell-beds. The author regards the Pampas formation, characterized by its gigantic fossil *Glyptodontia*, as equivalent to the older drift of Europe. Here and there outliers of Miocene and Eocene rocks rise like islands above the Pliocene plain, as, for instance, Parana and Cerro Hermoso, near Bahia Blanca. Taking a line from the last-named locality north-west to San Luis, we cross a country abounding in lakes, which have, however, no outflow, and we ascend a gradually rising declivity up to 300 metres (984 feet) above sea-level, leading us on to the flat, high, table-land of the Pampa Central. Though all the lakes, even the so-called freshwater ones, are more or less salt, no trace of marine organisms could be found. The uppermost formation in the Pampa Central is a white, calcareous marl (*tosca*), which gradually gives place to a conglomerate consisting of rounded porphyry-pebbles, lying unconformably on every other rock. Silicified tree-stems are found in the greyish-white marly sandstone (probably Oligocene) which forms the crags along the Rio Negro; this sandstone thins away between the Roca settlement and the confluence of the

Limay and the Neuquen, while the underlying dark red sandstone takes its place along the entire course of the Limay. Meanwhile the gradually rising Pampa table-land attains the level of 1,000 metres (3,280 feet) in the neighbourhood of the Cordillera. The saline nature of the soil becomes everywhere apparent, and the water of such rain-pools as are formed has, in consequence, a bitter salt taste. Gypsum does not occur.

The greatest depression in the Pampa is in the north, in the Vermejo and the Pilcomayo districts, and not (as Mr. Doering had asserted) in the great salt-lake of Urre-Lafquen, which lies 220 metres (723 feet) above sea-level. The author describes this lake as bounded south, west, and north-west by the Lihue-Calel mountains, and stretching away in other directions to an apparently limitless horizon, for there the lake is succeeded by a vast expanse of *salitrales* or salt-steppes, glittering in the sun like water.

Mountain-ranges occur dispersedly all over the region described by the author; in the north-east they consist mainly of granites and Palæozoic rocks, in the south-west of folded gneisses, granites, granitic gneisses and porphyries (Sierra Lihue-Calel), and amphibolites. In the Sierra Baya, at the German settlement of Hinojo, marble quarries are worked in the Silurian rocks. The yellow marble is topped by a quartzite of enormous thickness (this quartzite is the main component of the Tandil and Ventana mountains), and that again by a black, bituminous limestone. Three geographical miles south of Lihue-Calel the explorers came upon a ridge of mica-porphyrite (1,312 feet) containing very rich copper-ore veins. The Choique-Mahuida range which runs from the southern shore of Lake Urre-Lafquen along the right bank of the Curá-có is also porphyritic, and small porphyry ridges are seen along the route from the Rio Colorado to Choele-Choel. Great spreads of tuffs and porous lavas are traced for miles around the headwaters of the Alumine and the Collon-Cura, and along the Alumine valley rises a great chain of extinct volcanoes (6,560 feet) hitherto unmapped.

Evidence of glacial action occurs in the neighbourhood of Tandil in the shape of magnificent moraines, roches-moutonnées, ice-groovings, etc., and at the foot of the Cordillera in the shape of glacier-formed terraces. Peat-moors abound in the Cordillera, and also dangerous bogs (*menucos*) usually hidden by a luxuriant growth of herbage. These bogs are especially numerous in the vicinity of Lonquimay, on the upper Bio-bio and in Araucania. O. S. E.

IRON-ORE IN NORTHERN SWEDEN.

(1) *Om Routivare järnmalmsfält i Norrbottens län. By* WALFR. PETERSSON. *Geologiska Föreningens Förhandlingar, Stockholm,* 1893, *vol. xv., pages* 45-54, *and map.*

(2) *En ny jernmalmstyp representerad af Routivare Malmberg. By* HJ. SJÖGREN. *Ibid., pages* 55-63.

(3) *Ytterligare om Routivare jernmalm. By* HJ. SJÖGREN. *Ibid., pages* 140-143.

The iron-ore of Routivare, in Norrbotten, Sweden, is found in a hill rising from 520 to 585 feet above the surrounding country, and a few miles from Quickjokks. The ore consists chiefly of titaniferous magnetite, green spinel being an essential constituent, while olivine and decomposition-products of the same are subordinate. According to a series of analyses, the percentage of iron varies from 47·91 to 52·16; that of titanium from 1·35 to 13·05; and of phosphorus from 0·067 to 0·002. It contains no sulphur. The percentage of iron occasionally rises to 59. The area occupied by this ore is not extensive, being estimated at between seven and eight acres.

An eruptive rock, an olivine-gabbro, forms the hill in which the iron occurs. It is of interest to note that the ore consists chiefly of the same minerals as those that occur in the rock, since this lends countenance to the view that the former has been formed by some process of differentiation and concentration in the latter. The ore is considered to form a new type of iron-ore, and described as a magnetite-spinellite. Its commercial value is doubtful. Experimental smelting carried out in the laboratories of the Filipstad school of mines showed that the largest yield of iron (53·2 per cent.) resulted from the use of 10 per cent. each of limestone and of quartz. G. W. B.

HUNGARIAN IRON INDUSTRY.

Ungarns Eisenindustrie. *Von* FERDINAND BLEICHSTEINER. *Berg- und Hüttenmännisches Jahrbuch, Vienna,* 1893, *vol. xli., pages* 203-234.

The richest and purest ore and the thickest coal-seams occur in Transylvania. Yet no important works have been started there during the last ten years, and the mineral wealth of Transylvania seems to be reserved for future development.

The brown coal of Zsilthal in the department of Hunyad, is the most important deposit in Hungary. It occupies an area of 18½ by 3 miles. There are twenty seams of which eight are workable, and of which the thickness sometimes amounts to as much as 98 feet.

The coals of Borsoder and of Gömörer will play an important part in the future of the Hungarian iron industry. The seams in this case are not thick, but of great extent. They occur in strata which are much folded, and considerably faulted.

From the Gyalaer iron-ore mine, an ore, rich in manganese, free from phosphorus and sulphur, and containing 50 per cent. of iron, is obtained.

The ore used in the Borsoder works is exposed for a length of 4⅓ miles, and has a known thickness of 131 feet, but is supposed to average much more. An ore supplied from this mine contains over 50 per cent. of iron, occasionally rendered impure by copper pyrites. The winning of the ore is exceedingly cheap, as it is free from intercalations of barren and poor ore. It is roasted on the spot in furnaces, 30 feet high, with an expenditure of brown coal amounting to about 5 per cent. of the ore roasted. A machine is used for removing the 33 feet of marl and conglomerate which cover the ore-deposit without manual labour.

The largest mines and smelting-works in Hungary are concentrated in the Sajó-Rimathal district; the most extensive mine is that of Vashegy. It has three beds of ore, 39, 65, and 98 feet thick respectively. The lowest contains 20 per cent. of manganese and 40 per cent. of iron; the middle 2 per cent. of manganese and 50 per cent. of iron; and the uppermost often up to 60 per cent. of iron. Unfortunately the ore is not free from sulphur and copper, is difficultly fusible, and requires much lime in the furnace.

North Hungary possesses an area of many square miles of iron-ore, with an incalculable extent of forests for fuel. In other parts, as in the Banate, the iron-ores are poorer, and iron production more costly.

In Croatia, although iron-ore occurs not infrequently, the iron industry—partly on account of the cost of transport—has attained no marked development.

Smelting of iron-ores was carried on in Hungary in favourable places in early times. From this early beginning the present iron-smelting industry was developed at the end of last century. In bygone days charcoal could be obtained abundantly and cheaply from the extensive forests, but now it is dearer because the wood is

used for other purposes. In North Hungary small charcoal-furnaces, often worked with blowing engines and heated air, are in use. They produce grey iron. In 1891 there were 64 furnaces at work in Hungary, and 9 idle. G. W. B.

FRANCKEITE, A BOLIVIAN SILVER-ORE.

Ueber Franckeit, ein neues Erz aus Bolivia. By Alfred W. Stelzner. *Neues Jahrbuch für Mineralogie, Geologie, und Palæontologie, Stuttgart*, 1893, *vol. ii., pages* 114-124.

The mineral herein described is found in the district of Animas, a short distance south-east of Chocaya, and about 13,060 feet above sea-level. Chocaya is a township of the province of Chichas, Department of Potosi, and is situated about 105 or 110 miles south-south-west of the well-known city of that name. In Animas six argentiferous veins are known, bearing iron and copper pyrites, zinc blende, galena rich in silver, *llicteria* (franckeite), *polvorilla* (silver sulphide), argentiferous fahlores, dark ruby silver ore, and native silver. Here and there Jamesonite and Wurtzite also occur. The gangue-materials are quartz and kaolin, and less frequently baryta.

At Chocaya, clay-slates, presumably of Palæozoic age, predominate, and these are traversed by igneous rocks (dacites); the metalliferous veins are of later formation than the dacites.

The ore *llicteria*, described as consisting of lead, zinc, tin, and silver compounds, is invariably accompanied by *polvorilla*. In the Veta del Cuadro mine, *llicteria* occurs in direct association with iron pyrites and zinc blende as the latest band of the three forming the *veta* or vein. The mineral has the form of very thin flakes arranged radially like the petals of a flower. *Llicteria* from San Juan is in little spherules of radiate structure, average diameter ⅛ inch, ranging up to about ⅓ inch, sometimes massed together in reniform agglomerations. The mineral cleaves very perfectly in one direction, it is fairly malleable, makes slight marks on paper, has a greasy feel, and as it apparently does not scratch calcite its hardness is estimated at 2·75. The specific gravity is 5·55. The colour is blackish-grey to black, and the mineral possesses metallic lustre; it is opaque, even in extremely thin flakes examined under the microscope.

The chemical analysis was undertaken by Dr. C. Winkler, with the following results:—Heated in a tube closed at one end, from which the air has been completely expelled and replaced by carbon dioxide, a sublimate of germanium sulphide (GeS) comes off, rapidly giving place, on the admissson of air, to a thin film of germanium oxide (GeO_2). Heated in hydrochloric acid the powdered mineral gives off hydrogen sulphide, but dissolves only very sparingly. In *aqua regia*, on the other hand, it dissolves rapidly and easily, sulphur separating out. It also dissolves in hot nitric acid, leaving then a residue of white powder, consisting of the oxides of antimony, tin, and germanium. The exact quantitative determination of germanium was impracticable, on account of the small quantity of material available; the analyst estimates the percentage of germanium at 0·1, and there is also a fractional percentage of silver. Pure *llicteria* is estimated to contain:—Lead, 55·55 per cent.; tin, 13·56 per cent.; antimony, 11·55 per cent.; sulphur, 19·34 per cent. This analysis leads to the formula $5PbS + 2SnS_2 + Sb_2S_3$. Dr. Kollbeck subsequently determined the silver content of several specimens in the dry way, and found the varying percentages of 0·857, 1·040, and 1·037 Ag. The variation is probably due to the very intimate association of the *llicteria* with *polvorilla* and other ores richer in silver, and it is very possible that in hand-picking in large

quantities the miners cannot very well separate one from the other; hence, the perhaps undeserved reputation (in Bolivia) of *Llicteria* as a silver-ore. In its form, in its physical properties, and in its qualitative composition this mineral strikingly resembles plumbostannite (already known from Moho in Peru), but not in quantitative composition. The difference will be seen by comparing with the above analysis of *Llicteria* that of plumbostannite given by Dr. Raimondi:—Lead, 30·66 per cent.; tin, 16·30 per cent.; antimony, 16·98 per cent.; sulphur, 25·14 per cent.; iron, 10·18 per cent.; zinc, 0·74 per cent. Under all the circumstances, the author concludes that *Llicteria* is a new mineral species, for which, in compliment to the mining engineers, Messrs. Carl and Ernst Francke, he proposes the name Franckeite.

O. S. E.

THE NEW BOLIVIAN SILVER MINERAL CYLINDRITE.

Ueber den Kylindrit. By A. FRENZEL. *Neues Jahrbuch für Mineralogie, Geologie, und Palæontologie, Stuttgart,* 1893, *vol. ii., pages* 125-128.

The name cylindrite is applied to this mineral because of its remarkable cylindrical or rolled form; in section, the cylindrical rolls show a concentric structure reminding one of the appearance of a roll of paper, and looked at singly, they appear to the observer more like a piece of man's handiwork than a natural product. The mineral occurs at the Santa Cruz mine, Poopó (Bolivia), a district where for many generations silver, tin, copper, and lead-ores have been worked in the Silurian strata of the Cordillera (12,431 feet above sea-level).

Cylindrite has a bright metallic lustre, blackish leaden-grey colour, a black streak, and makes black marks on paper. It is moderately brittle, its hardness varies from 2·5 to 3, and its specific gravity (according to two determinations) is 5·42. Chemical analysis gave the following percentage results:—Lead, 35·41 per cent.; silver, 0·62 per cent.; iron, 3·00 per cent.; antimony, 8·73 per cent.; tin, 26·37 per cent.; sulphur, 24·50 per cent.; total, 98·63 per cent. The quantitative proportions, deduced from this analysis are:—3·1 Pb Ag Fe; 1 Sb; 3 Sn; 10·5 S; suggesting the formula:—$3\ PbS.\ Sb_2S_3 + 3\ (PbS.\ 2\ SnS_2)$.

Germanium was specially tested for, but not found. Acids in the cold do not attack the mineral, but hot hydrochloric acid dissolves it gradually, and so too hot nitric acid, sulphur and the insoluble white oxides of tin and antimony separating out. It may be noted that cylindrite, plumbostannite, and Franckeite occur along a line ranging west of Lake Titicaca y Aullagas, from Huancané in Peru to Potosi in Bolivia. The first-named mineral is the southernmost occurrence, the second the northernmost, and the third lies between the two. O. S. E.

MANGANESE ORES.

Minerais de Manganèse analysés au Bureau d'Essais de l'Ecole des Mines de 1845 *à* 1893. *By* ADOLPHE CARNOT. *Annales des Mines,* 1893, *series* 9, *vol. iv., pages* 189-212.

Ores of manganese are principally employed in the metallurgy of iron, in the preparation of oxygen, chlorine, and in glass works. This paper records the analyses made between 1845 and 1893 in the laboratory of the School of Mines, Paris, of 207 manganiferous ores, of which 145 are of French origin, and 62 from foreign countries, viz.:—Germany, 7; Spain, 28; Greece, 2; Austria, 1; Italy, 5; Russia, 6; Switzerland, 3; Turkey in Europe, 3; and Turkey in Asia, 7.

In the analyses care has been taken to determine the amount of phosphoric acid, of silica and clay (alumina?), of iron, copper, and cobalt oxides, and of the alkaline earths (baryta, lime, magnesia); and in every case the proportion of metallic manganese has been calculated. In fact, the tables of analyses have been so arranged as to be specially useful to glass manufacturers, iron founders, and the owners of chemical works. M. W. B. AND O. S. E.

MERCURY MINING IN THE WIPPACH VALLEY, CARNIOLA, AUSTRIA.

Bericht über den Stand des Quecksilber-bergbaues im Wippachthale in Innerkrain. By CARL MOSER. *Verhandlungen der k.k. geologischen Reichsanstalt, Vienna,* 1893, *pages* 238 *and* 239.

The discovery of native mercury two or three years ago in the Eocene sandstones of Mance near Wippach impelled a local company to make trial-diggings for the metal in that district. A preliminary trial was made at the precise spot where the mercury had first been found, but when it was ascertained that the mercury dwindled away in depth and that nothing else in the shape of an ore-formation was visible, the company commenced washing the sands and gravels accumulated at the mouths of the Wippach springs. Here quicksilver was found in little drops amongst the alluvia, and this find encouraged the promoters to have an adit driven, 335 feet long, in the slope of Mount Nanos in the direction of the presumed subterranean course of that branch of the Wippach which gushes forth at the Vollmundloch; they came here to loamy beds full of angular limestone-fragments, but the adit was ultimately abandoned because the repeated invasion of water made continuous working impossible. A similar result attended the mining operations started in the Bela cave beneath the Starygrad, but a third adit has been driven 144 feet into the heart of Mount Nanos, through highly fossiliferous Cretaceous limestones, and is to be continued by means of the Brand boring-machine, for which water-power will have to be got.

Several experimental washings of Wippach sand have been made and a large sample got in the spring of 1893 assays 0·02 per cent. mercury at a depth of 3 feet. At this depth barren clays and loams mixed with limestone-pebbles suddenly come in; and not only is the thickness of the mercury-bearing sands insignificant, but their area is small. The author concludes that they are not worth working from the industrial point of view, and suggests the possible discovery of the original mercury deposit within Mount Nanos. O. S. E.

THE MEERSCHAUM OF PRNJAVOR, BOSNIA.

Meerschaum aus Ljubic-planina bei Prnjavor in Bosnien. By M. KISPATIC. *Verhandlungen der k.k. geologischen Reichsanstalt, Vienna,* 1893, *pages* 241-242.

Chemical analysis shows that this mineral, worked on the north-western slope of the Ljubic-planina for the manufacture of tobacco-pipes, is of very similar composition to the meerschaum occasionally found in Asia Minor and Greece. The percentages are: silica, 61·09; magnesia, 25·87; iron sesquioxide, 2·59; and water, 10·47; plus 14 per cent. of hygroscopic water from an air-dried sample. There are no traces of carbonates or of lime. Magnesite is often found to accompany meerschaum, containing as an impurity more or less hydrosilicate of magnesia.

O. S. E.

PETROLEUM IN FRANCE.

Couches à Pétrole des environs de Pechelbronn (Basse-Alsace). Températures exceptionnellement élevées qui s'y manifestent. By A. DAUBRÉE. *Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences*, 1893, *vol. cxvii., pages* 265-269.

Introduction.—Within the last twelve years a complete change has occurred in the working of the petroleum contained in the Tertiary measures near Pechelbronn, in Lower Alsace. Instead of a slow and troublesome working of the bituminous sand by pits and drifts, a new, more simple, and more productive process has been introduced. Bore-holes have tapped the mineral oil, which sometimes rises to the surface, or sometimes requires to be raised to the surface by pumping.

This new mode of working has disclosed many facts worthy of interest, especially a subterranean wealth in petroleum and hydrocarbon gases, whose existence has hitherto been unsuspected, as well as abnormal subterranean temperatures.

Production.—The drowning-out of a deep drift by petroleum in 1881 suggested to Mr. Le Bel the idea of using bore-holes instead of underground mining. The first borings, although not exceeding a depth of 450 feet, found flowing wells of petroleum, and the first dozen wells produced from 40 to 50 tons of mineral per day. In consequence of this unexpected discovery, a concession was acquired by a company, who made extensive explorations, both in the neighbourhood of the existing field as well as in other parts of the area conceded, and carried out the exploration to much greater depths.

At the present time the borings are more than 500 in number, and although not very far apart, they have furnished very different results. Some have produced nothing, in others the subterranean gases have forced the mineral oil to the surface with considerable violence. Since 1882, 41 flowing wells have been discovered. The flowing wells are not usually of long duration, seldom more than 3¼ years. From one of them (No. 186), discovered in 1884, 8 tons per day are still produced. Usually the force of the gases is gradually reduced, and pumps are finally used to pump the oil, accompanied with brine.

The volume of the subterranean gases is sometimes very large. One of the wells (No. 394) produced a volume of 400,000 to 500,000 cubic feet of gases per day, together with mud and small stones, for a period of six weeks, during which time its intensity gradually decreased. The flow of petroleum is usually so sudden that the workmen are soaked with it.

The pumps worked at low-pressure wells usually furnish brine; at one of them, near Kutzenhausen, there was 19·7 per cent. of salt. Mr. Berthier, who analysed sixty years ago the mother-liquor of the Soultz-sous-Forêts salt works, which is derived from the same petroleum-bearing measures, stated that it contained no sulphates, but on the other hand, was very rich in bromine, which could be extracted with profit. These two characteristics are found in the brine-well of Kreutznach, which flows from porphyry, and which had also been examined by Mr. Berthier. The same characteristics are found in the brine from recent borings, as proved by Mr. Wilm's analyses. These two distinctive characteristics of the brine-waters of petroleum-bearing strata are very remarkable.

A boring made in 1890, near Surbourg, to a depth of 810 feet, at first had a daily yield of 7½ tons of petroleum, which gradually fell to 4 tons, the present figure. Another boring, however, more distant from Surbourg, yielded from 5 to 10 tons of petroleum per day, and has yielded 3,000 tons in one year.

The constancy of the petroleum is shown by No. 146 well, which has yielded in ten years, up to the present time, 10,420 tons of petroleum, of which 3,002·9 tons were flowing and 7,417·1 tons were obtained by pumping, which is still continuing.

The present working wells are producing 80 tons per day from both flowing and pumping wells.

It may be remarked that the produce of the principal wells would have been much greater if the diameter of the wells had been as large as those bored at Baku; moreover, the wells are not pumped at nights, owing to the oil-works being too small. The production of several wells near Pechelbronn is large, even when compared with similar wells in Pennsylvania or Baku. This abundance is very remarkable when it is compared with the previous area of working with pits and drifts. Formerly, forty workmen mined the black bituminous sand, which, treated with boiling water, yielded 1·6 per cent. of its weight of mineral oil, only producing from 70 to 80 tons of petroleum per annum.

The weight of petroleum sold since 1881, the time of the first well, until April, 1893, from the Pechelbronn royalties is 69,529·685 tons, of which 27,086·8 tons were produced prior to December 31st, 1888, and 42,442·885 tons since the re-construction of the company. These figures are equivalent to a mean annual produce of 5,700 tons; that is, seventy times greater than that produced from pits and drifts.

Temperatures.—More than forty years ago, in describing the petroleum-bearing sands in the Tertiary measures of Pechelbronn, the author stated that the workings were then shallow, and that the internal temperatures presented a more than usual increase. One water-spring, in a shaft at a depth of 230 feet, had a temperature of 57 degs. Fahr., which corresponds (the temperature at the surface being at 50 degs. Fahr.,) to a mean of 1 deg. Fahr., per 33 feet.

Thermometrical measures made in several of the wells recently bored, have not only confirmed this statement, but have shown that this increase is much more rapid than the author formerly supposed. In No. 445 well, near Soultz-sous-Forêts, at a depth of 584 feet, the water had a temperature of 75 degs. Fahr., or a mean increase of .1 deg. Fahr., per 23 feet. A well bored in Haguenau forest by a German company showed, at a depth of 2,040 feet, a temperature of 141 degs. Fahr. The temperatures taken in this boring at different depths are worthy of interest, and are shown in the following table:—

Depths in Feet.	Temperatures in Degs. Fahr.
1,000	117·5
1,083	120·5
1,181	128·7
1,312	135·5
1,378	137·7
1,575	137·7
1,673	140·0
1,772	139·0
1,903	139·0
1,969	141·0
2,034	141·0

These results are in direct contradiction to the rule derived from a very large number of observations, and especially of those made by M. d'Arago at the Grenelle artesian wells; the temperature in the petroleum wells augmenting rapidly in depth, the geothermometric degree diminishes as the depth is increased.*

* The geothermometric degree is the vertical height descended for an increase of 1 deg. Fahr.

Near Kutzenhausen, No. 457 well has shown a more rapid increase; as at a depth of 460 feet the temperature of the water was 86 degs. Fahr., this gives 1 deg. Fahr. per 12 feet. M.W.B.

PETROLEUM IN THE SHERANI HILLS DISTRICT, INDIA.

Geology of the Sherani Hills. By TOM D. LA TOUCHE. *Records of the Geological Survey of India,* 1893, *vol. xxvi., pages* 77-96, *with map and five plates.*

The only mineral of practical importance found in the Sherani Hills district is petroleum, which occurs in small quantities, near the village of Moghal Kot, where it oozes at several points from a thick band of quartzose sandstone, and is collected from shallow pits dug in the sand on banks of the river Toi.

The crude oil is of excellent quality, but it does not occur in sufficient quantities to be of commercial value. It is suggested that the flow might be increased by boring, but the geological conditions are not such as to lead one to anticipate that large accumulations of oil may be found.

The existence of coal has been reported near Moghal Kot and at Chaukhel Dhana.

M. W. B.

THE ORIGIN OF PETROLEUM.

Zur Frage über die Bildung des Erdöls. By J. J. JAHN. *Jahrbuch der k.k. geologischen Reichsanstalt, Vienna,* 1892, *vol. xlii., pages* 361-376.

In studying the Silurian rocks of Bohemia, the author found in a dolomite of the Pridoli valley that the hollow portions of fossils—such as the chambers of Orthoceratidæ, or the space enclosed by the two valves of a Lamellibranch—often contained a sort of nucleus of little lumps of anthracite or drops of petroleum (sometimes both substances), while the rest of the drusy hollow was taken up by calcite or dolomite-crystals. The same occurrence is noticeable in the limestones near Stolba, and not only are the anthracite-lumps and petroleum found in immediate connexion with the fossils, but they, as well as mineral wax, occur dispersedly in the mass of the rock itself. These substances, whether in intimate connexion with the marine shells or apart from them, are evidently the result of the decomposition of the animal organisms which, ages ago, were buried in the calcareous mud of the Silurian sea. The author considers that his observations herein confirm the views of Prof. C. Engler, who attributes the origin of petroleum to animal organic remains, and has succeeded in artificially producing that substance and its bye-products from animal matter. But it is now seen that the idea that the occurrence of coal in quantity necessarily implies paucity of petroleum, or the abundance of the latter the scarcity of the former, in any particular locality, is erroneous. Wherever the Silurian limestones of Bohemia contain anthracite, there too, either petroleum or bitumen is found, and one is impelled to conclude that the formation of coal by the decomposition of vegetabe matter went on concurrently with the formation of petroleum by the decomposition of animal matter. The author thinks, moreover, that some anthracite may well be of animal origin, it may arise, say, from the decomposition of masses of the chitinous skeletons of Graptolites (anthracitized Graptolite-remains actually occur in bituminous-calcareous strata

of Étage E). The conditions of temperature and pressure which Prof. Engler found necessary in his experimental manufacture of petroleum, probably obtain in nature as a result of the crumpling and crushing of the earth's crust and of the eruptions of igneous rock which not seldom accompany those phenomena. It is a striking fact in this connexion that the Stolba limestones become more dolomitized as they approach the neighbouring eruptive rock (diabase). O. S. E.

DETERMINATION OF PHOSPHORUS IN IRON, STEEL, ETC.

(1) *Sur la Détermination du Phosphore dans les Fers, les Aciers, et les Fontes. By* ADOLPHE CARNOT. *Annales des Mines*, 1893, *series* 9, *vol. iv., pages* 5-10.

(2) *Sur la Détermination du Phosphore dans les Terres Végétales. By* ADOLPHE CARNOT. *Annales des Mines*, 1893, *series* 9, *vol. iv., pages* 11-14.

As regards the determination of phosphorus in iron and steel, the author states that he has taken care to avoid the calcination of iron nitrate, the use of hydrochloric acid, and the transformation of magnesium phosphomolybdate into the pyrophosphate, all of which are, in his view, so many contributing causes to inaccuracy.

Five grammes of iron or steel having been dissolved in 40 cubic centimetres of pure nitric acid, and the solution then treated with 10 cubic centimetres of concentrated sulphuric acid, heated, evaporated, dried, redissolved in 50 cubic centimetres of boiling water, washed on to a filter and decanted into a half-litre flask, the silica residue which remains on the filter is freed from manganese peroxide by treatment with a little concentrated hydrochloric acid; from graphite by calcination; and the weight of white silica-residue multiplied by the coefficient 0·4667 gives the exact proportion of silicon present. The organic matter in the filtrate is got out by boiling for 30 minutes, with the addition of 1 gramme of chromic acid; then 4 grammes pure ammonium sulphate is added to the liquid, and 50 cubic centimetres of the ordinary molybdic solution at 5 per cent. is poured in, and the whole kept at 100 degs. Cent. for at least one hour. The precipitation being ascertained to be complete, the precipitate is dissolved in 30 cubic centimetres of ammonia diluted with an equal quantity of warm water; this is gradually neutralized by means of nitric acid, and the resulting yellow precipitate of ammonium phosphomolybdate is brought on to a weighed filter-paper over which the solution has been decanted, dried in an oven at 100 degs. Cent., and weighed in a wide-mouthed flask. The author claims that this second precipitation enables the analyst to obtain a residue of constant composition, free from iron and from excess of molybdic acid. The weight of contained phosphorus is found by multiplying the weight of the dried precipitate into the coefficient 0·01628. (The author made a special analysis of ammonium phosphomolybdate, and his formula differs from those of Messrs. Debry, Rammelsberg, Finkener, and Gibbs; he finds that the compound contains 1·628 per cent. of phosphorus.)

The determination of phosphorus in soils differs, of course, in its details from the above, but is like the preceding, based on the principle of double precipitation. Preliminary roasting is found necessary to get rid of the greater part of the organic substances, particularly in soils containing much humus; and the use of sulphuric acid for isolating the silica is avoided because of the possible precipitation of sparcly soluble calcium sulphate. O. S. E.

NEWFOUNDLAND.

QUANTITY AND VALUE OF MINERALS EXPORTED FROM NEWFOUNDLAND TO THE END OF 1891.

Taken from the Customs Returns, as published in the Journals of the House of Assembly. By J. P. HOWLEY, 1892.

Years.	Copper.						Nickel Ore.		Lead Ores.			Iron Pyrites.		Other Minerals and Ores.		Total Values of Ores, etc., exported.
	Ore.	Regulus.	Ingots.	Value of Ore.	Value of Regulus and Ingots.	Total Value Copper Ores, etc.		Value.			Value.		Value.		Value.	
	Tons.	Tons.	Tons.	$	$	$	Tons.	$	Tons.	Cwt.	$	Tons.	$	Tons.	$	$
1854 to 1864	627½	..	..	22,960	..	22,960	..	..	2,250	0?	90,000?	..	..	..	..	112,960
1865	236	..	..	8,496	..	8,496	..	..	313	5	15,036	..	..	Slate 31,000	1,240	24,772
1866	283½	..	..	10,206	..	10,206	..	..	5	0	240	..	..	..	..	10,446
1867	79	..	..	2,370	..	2,370	..	..	..		..	..	..	50	600	2,970
1868	None.	..	..	..	..	..	..	.	0	4	8	..	..	101,000	2,020	2,028
1869	3,422	..	..	109,504	..	109,504	2½	600	0	2	4	..	..	..	..	110,104
1870	5,226	..	..	167,232	..	167,232	38	9,120	..		..	..	..	..	..	176,352
1871	1,407	..	..	45,024	..	45,024	7	700	..		..	..	..	..	..	45,720
1872	4,955	..	..	588,560	..	588,560	8	2,560	..		..	..	..	..	..	591,120
1873	5,553	..	..	194,355	..	194,355	120?	3,600	..		..	..	..	..	..	197,955
1874	5,062	..	..	121,248	..	121,248	98	4,704	130	0	6,240	..	..	6,000	120	132,312
1875	10,018	..	..	370,666	..	370,666	17½	5,520	95	0	4,560	..	..	6,000	120	378,566
1876	25,134	..	..	614,700	..	614,700	28	2,800	38	0	1,824	..	..	..	..	619,324
1877	47,454	..	..	1,264,004	..	1,264,004	..	..	10	0	1,392	..	..	..	..	1,265,396
1878	35,823	750	..	788,106	34,500	822,606	..	..	2	0	100	..	..	..	..	822,706
1879	28,405	1,112½	..	511,290	44,500	555,790	..	..	..		..	..	..	..	..	555,790
1880	22,042	21	..	440,840	840	441,680	..	..	..		..	..	..	..	..	441,680
1881	27,351	..	..	547,020	..	547,020	..	..	..		..	..	..	..	..	547,020
1882	19,004	260	..	456,096	12,480	468,576	..	..	..		..	..	..	..	..	468,576
1883	11,989	353	..	239,780	16,944	256,724	..	..	..		..	10?	72	..	..	256,796
1884	4,079	385	..	73,422	25,795	99,217	..	..	..		..	950?	7,600	..	..	106,817
1885	4,401	300	..	88,020	14,400	102,420	..	..	..		..	..	..	..	..	102,420
1886	235	6,678	24½	3,760	242,390	246,150	..	..	..		..	..	..	..	..	246,150
1887	7,491½	..	120$\frac{1}{10}$	119,864	49,000	168,864	..	..	..		..	410	8,200	Mica 12 lbs.	240	177,304
1888	3,322	1,290	1,208½	66,440	749,946	816,386	..	..	10	0	400	1,850	37,000	..	..	853,686
1889	2,306	761	1,343	46,120	310,250	356,370	..	..	..		..	7,530	64,000	..	..	420,370
1890	400	1,236	609	3,400	223,392	226,792	..	..	..		..	8,670	72,315	Antimony	1,200	300,307
1891	7,060	3,626	1,139	63,540	502,310	565,850	..	..	..		..	19,150	57,900	Do.	1,000	624,750
	283,355½	16,772½	4,441$\frac{1}{10}$	6,967,043	2,226,747	9,193,790	319	29,604	2,853	11	119,804	38,570	247,087	144,050	6,540	9,594,717

THE CAPELL AND GUIBAL VENTILATORS CONTRASTED.

Mittheilungen über eine grosse Ventilations-Anlage nach dem Patente Capell auf Zeche Prosper I bei Berge-Borbeck. By M. KATTWINKEL. *Zeitschrift für das Berg-, Hütten- und Salinen-Wesen im Preussischen Staate*, 1890, *vol. xxxviii., pages* 347-349.

The Prosper I. pit, in which 1,000 workpeople are employed, was until recently fitted with a Guibal ventilator, with a diameter of 39½ feet. This was found insufficient for the proper ventilation of the workings, and a Capell ventilator was put up instead. The new ventilator was tested in July, 1890. At 72 revolutions there was a mean air-velocity in the upcast shaft of 1,590 feet per minute, and the cross section being taken as about 52 square feet, the amount of air passing through per minute would be about 82,600 cubic feet.

In the downcast shaft, at the same number of revolutions, the average velocity was 1,790 feet per minute, giving, with a cross section of 59 feet, about 105,600 cubic feet per minute.

Further experiments were made at 80 and 87·5 revolutions, and the useful effect was found to lie between 51 and 53 per cent. of the steam-power used, or 7·6 times the useful effect obtained with the Guibal fan.

Attention is drawn to the lubricant used, which consisted of finely comminuted suet, over which a fine stream of water was made to trickle continuously; it was thus possible to keep the bearings quite cool, a *desideratum* unobtainable with the other lubricants (oil, tallow, etc.) used on previous occasions. O. S. E.

THE VENTILATING APPARATUS AT THE HEILBRONN SALTWORKS.

Die Grubenventilatoranlage auf dem Salzwerk Heilbronn. By FR. BUSCHMANN, 1893. *Zeitschrift des Vereines Deutscher Ingenieure, vol. xxxvii., pages* 29-34, *with figures in the text.*

The plant now in use was erected in the rock-salt mine at the beginning of 1892 at a moderate cost, and shows comparatively favourable results. The local conditions were such as to favour the use of a small, quick-running ventilator, and the author points out that the comparisons frequently drawn between large and small ventilators, to the detriment of the latter, are now proved to be untrustworthy.

The Pelzer ventilator works unilaterally, and is a combination of the helical (screw) and centrifugal ventilators, having straight and centric blades. This combination permits of a relatively large inlet with a fan of small dimensions. The conical fan-wheel has a diameter of 5¼ feet, with a rim-breadth of 16 inches. The radially-arranged twelve blades are so placed that three pairs of diametrically opposed blades reach to the nave of the fan-wheel, while the six intervening blades are left short of it to allow space for the central inflow of air. These shorter blades are joined by means of a screw passing through the wheel-nave, so as to neutralize the pulling strain due to centrifugal power. The wheel-nave is prolonged backwards into a cone that meets the conical casing to which the blades are fixed. In front of the fan-wheel, and joined thereto by a sheet-iron cylinder, is the helical ventilator (diameter 5 feet, rim-width 11 inches), this also has twelve blades which are riveted to those of the fan-wheel and to the sheet-iron cylinder. The axle or shaft of the ventilator is 7¼ feet in length, with an average diameter of 3 inches.

The ventilator is driven by the principal driving-shaft of the salt-grinding mill, the necessary power being transmitted thence by a manila-hemp rope which has been dipped in tar. The steam engine is a single-cylinder one (cylinder 21 inches in diameter, and 40 inches stroke).

Elaborate arrangements were made for the purpose of measuring the efficiency, etc., of the ventilator, and for the velocity-measurements a Casella anemometer was used, the constant of which is 10, and the time-limit selected for each measurement was 10 minutes. The experimental results are roughly expressed in tabular form as follows:—

No. of experiment	1	2	3	4	5
Revolutions of engine per minute	40	45	50	55	60
Indicated power of engine (h.p.)...	8·505	10·598	12·956	15·565	18·460
Revolutions of fan per minute ...	184	206	228	249	270
Volume of air per minute (c. feet)	33,853	36,006	38,477	40,595	43,419
Water-gauge—					
Theoretical depression $H = \frac{yu^2}{g}$ (inches)	1·172	1·470	1·800	2·149	2·528
Observations—					
Depression h_1 (inches) ...	0·394	0·512	0·669	0·827	0·984
Compression h_2 (inches) ...	0·551	0·630	0·709	0·827	0·945
Water-gauge h (inches)... ...	0·945	1·142	1·378	1·654	1·929
Correction of water-gauge for velocity h_3 (inches)	0·193	0·220	0·252	0·279	0·322
Observed water-gauge $H_1 = h - h_3$ (inches)	0·752	0·920	1·126	1·375	1·607
Manometric efficiency $H_1 \div H$ ..	0·641	0·626	0·625	0·639	0·635
Power in the air (horse-power) ...	4·062	5·306	6·931	8·914	11·067
Mechanical efficiency	0·472	0·500	0·535	0·575	0·599

All the experiments appear to have been made on February 17th, 1892, between the hours of 3·52 p.m. and 7·30 p.m. The temperature aboveground at the time varied between 20 and 27 degs. Fahr., while in the airway at the ventilator it was uniformly 58 degs. Fahr.; and the height of barometer was 29·75 inches.

The total cost of the ventilator, including labour for putting it up, gear for transmission of power, and measurement appliances, was £120. The daily working expenses at 18 horse-power and 42,360 cubic feet per minute, including 5 per cent. for depreciation, do not exceed 2s. 9½d. M. W. B. and O. S. E.

A DOUBLE VENTILATING FAN.*

Verbundventilator. By C. Wenner. *Zeitschrift des Vereines Deutscher Ingenieure,* 1893, *vol. xxxvii., pages* 14-15. *With two figures.*

The ventilator herein described is apparently an improved form of an apparatus, in which two fans (instead of being concentrically arranged) are placed side by side and combined into one double fan. The two casings with their appropriately shaped blades are separated from one another, and closed up laterally by the solid disc carrying the blades. The double fan, being thus all of one piece, is driven by a single pulley or drum. Further, the double-walled fan-chamber is divided by the fan-disc into two compartments, an outer and an inner, and the air-current

* English patent, No. 13,725 of 1892.

takes the course which will be now described. Sucked in at one fan-inlet the air is thrown off at the periphery of the first fan at a certain pressure into the outer chamber through which it streams, around and outside the inner fan-chamber on the other side of the double fan. The air-current then enters through the inlet of the second fan, and at the periphery is thrown off into the inner chamber or casing, from which it passes to the conical outlet of the double fan.

The general formula for the depression or water-gauge produced by such a double ventilator is thus arrived at: Let

v = velocity of periphery of double fan;
h_1 = water-gauge in outer chamber or casing;
h_2 = water-gauge in inner chamber or casing; and
k = a coefficient,

then, in an ordinary case where the ventilator sucks in air from the free atmosphere, the air-pressure produced by the first fan in the outer casing is expressed by the equation:—

$$h_1 = k \frac{v^2}{125^2}. \qquad (a).$$

That produced by the second fan, which exhausts air from the outer casing at the pressure h_1. being expressed by $h_2 - h_1 = k \frac{v^2}{125^2}$, consequently

$$h_2 = k \frac{v^2}{125^2} + h_1. \qquad (b).$$

Then, taking for the value of h_1 that given in (a), we obtain:

$$h_2 = k \frac{v^2}{125^2} + k \frac{v^2}{125^2} = 2k \frac{v^2}{125^2}. \qquad (c).$$

This value is exactly twice the depression or water-gauge that an ordinary ventilator, whose dimensions are one-half those of the double fan, would produce, other circumstances being similar.

The result of an experiment with a double ventilator, with a fan-diameter of 2 feet, at a speed of periphery of 102 feet per second, showed 6 inches of water-gauge at the conical outlet, the measurements being taken in the issuing air-current.

O. S. E.

VENTILATING FANS.

Les Ventilateurs de Mines: Rapport de la Commission instituée pour l'Étude des Ventilateurs, par la Direction de l'Industrie de la Société Générale pour favoriser l'Industrie nationale. By H. MATIVA, E. DESVACHEZ, I. ISAAC, *and* N. EVRARD. *Revue Universelle des Mines,* 1892, *series* 3, *vol. xx., pages* 133-187, *and plates V.-VIII.*

The experiments detailed in the following table were made on four different types of mining fans—viz., the Guibal, Capell, Ser, and Rateau. Four experiments were made on each of these fans at different mines, and one failing, there are fifteen, which are detailed in the following table.

The Committee give the approximate cost of the different fans, including the steam-engine for driving, foundations, and building for covering, as follows:— Guibal, £1,120; Ser, £1,280; Capell, £1,380; and the Rateau, £1,200; and they summarize the four different fans thus. They are all efficient from many points of view, and possess good qualities, but the Rateau appears to possess advantages which place it first, as it produces a higher pressure, has a higher mechanical efficiency, and works regularly and silently.

B. D.

RESULTS OF EXPERIMENTS ON FANS.

Experiment Number.	Description of Fan.	Name of Colliery.	Years in Use.	Cost of Installation. Total.	Cost of Installation. Fan only.	Dimension of Fan. Diameter.	Dimension of Fan. Width.	Dimension of Fan. Diameter of Inlet of Fan.	Dimensions of Cylinders of Engine. Diameter of Piston.	Dimensions of Cylinders of Engine. Stroke.	Revolutions per Minute. Engine.	Revolutions per Minute. Fan.	Speed of Periphery of Fan per Minute.	Indicated Horse-power.	Sectional Area of Air drift where measured.	Air per Minute. Speed per Minute	Air per Minute. Volume per Minute.	Water-gauge. Observed.	Water-gauge. Calculated for Rim Speed of 6,888 Feet.	Theoretical Work of Air Displaced.	Equivalent Orifice.	Mechanical Efficiency.	Manometric Efficiency, Vacuum.
				£	£	Feet.	Feet.	Feet.	Inches.	Inches.			Feet.		Sq. Ft.	Feet.	Cu. Ft.	Inches.	Ins.	H.P.	S. Ft.		
1	Guibal	Levant du Flénu Cuesmes	15	1,240	311	39·36	8·20	13·12	26¾	33½	46	46	5,683	76·54	50·05	2,434	121,900	2·16	3·27	41·60	31·75	0·543	
									Fan driven	direct.	56	56	6,919	138·56		2,714	135,842	3·31	3·17	70·82	28·63	0·511	
											65	65	8,032	202·67		3,184	159,423	4·21	3·09	105·87	29·70	0·522	
																		Means	3·18		30·02	0·525	0·539
2		Marcinelle Nord	9⅓	1,200	256	....	....	....	24·40	39·37	50	50	6,180	49·10	43·04	1,210	58,125	2·87	3·53	23·61	11·72	0·399	
									Fan driven	direct.	60	60	7,417	88·51		1,426	61,048	4·09	3·66	39·66	11·62	0·448	
											70	70	8,647	150·03		1,631	70,262	5·79	3·57	64·09	11·19	0·427	
																		Means	3·586		11·51	0·424	0·607
3		Dampremy	5½	1,236	270	29·53	6·89	9·84	24·40	33·46	40	64	5,931	57·69	70·37	879	61,941	3·07	3·970	29·98	13·56	0·520	
									Fan driven	by belt.	47	75	6,950	88·32		976	68,733	4·01	3·697	46·14	13·13	0·522	
											53	85	7,877	116·48		1,021	71,908	4·84	4·130	54·89	12·48	0·471	
																		Means	3·94		13·02	0·504	0·667
4		Horloz à Tilleur	¾	1,120	180	19·02	6·40	6·89 Two Inlets	16·50	29·52	100	100	5,972	80·87	83·06	1,173	97,469	3·15	4·19	48·39	20·68	0·598	
									Fan driven	direct.	106	106	6,331	99·04		1,259	10,476	3·54	3·92	58·96	21·41	0·595	
											120	120	7,167	123·46		1,348	10,605	4·25	4·18	75·09	20·98	0·608	
																		Means	4·18		21·09	0·600	0·694
5	Ser	Davy	3½	720	240	4·59	0·79	2·79	11·81	25·6	65	336	4,843	10·50	34·22	535	1,832	1·456	2·76	4·21	5·81	0·401	
									Fan driven	by belt.	75	391	5,636	16·63		639	2,189	1·850	2·94	6·38	6·13	0·384	
											85	435	6,927	21·82		775	2,655	2·244	2·74	9·39	6·78	0·430	
																		Means	2·81		6·24	0·405	0·477
6		Dutemple	4$\frac{5}{12}$	820	300	5·25	0·92	3·11	13·9	29·5	63	302	4,976	25·08	66·389	623	4,144	1·93	3·93	12·60	11·41	0·503	
									Fan driven	by belt.	73	345	5,683	37·11		759	5,046	2·68	3·69	21·30	11·83	0·574	
											80	377	6,212	46·32			5,373	3·07	3·77	26·00	11·72	0·562	
																		Means	3·79		11·62	0·546	0·643

RESULTS OF EXPERIMENTS ON FANS.—*Continued.*

Experiment Number.	Description of Fan.	Name of Colliery.	Years in Use.	Cost of Installation: Total.	Cost of Installation: Fan only.	Dimension of Fan: Diameter.	Dimension of Fan: Width.	Dimension of Fan: Diameter of Inlet of Fan.	Dimensions of Cylinders of Engine: Diameter of Piston.	Dimensions of Cylinders of Engine: Stroke.	Revolutions per Minute: Engine.	Revolutions per Minute: Fan.	Speed of Periphery of Fan per Minute.	Indicated Horse-power.	Sectional Area of Air-drift where measured.	Air per Minute: Speed per Minute.	Air per Minute: Volume per Minute.	Water-gauge: Observed.	Water-gauge: Calculated for Rim Speed of 6,888 Feet.	Theoretical Work of Air Displaced.	Equivalent Orifice.	Mechanical Efficiency.	Manometric Efficiency, Vacuum.
				£	£	Feet.	Feet.	Feet.	Inches.	Inches.			Feet.		Sq. Ft.	Feet.	Cu. Ft.	Inches.	Ins.	H-P.	S. Ft.		
7	Ser	Moulin	2½	1,280	480	6·36	1·18	3·84	19·7 Fan driven	27·6 by belt.	57 67 72	302 365 382	6,220 7,270 7,870	45·06 74·66 88·88	43·420 23·02	1,422 / 305 1,635 / 358 1,895 / 391	75,966 87,487 10,130	1·614 2·362 2·677	2·09 1·98 2·05	19·33 32·71 42·76	22·92 21·73 23·67	0·429 0·438 0·481	
																		Means	2·04		22·70	0·449	0·345
8		St. Mark	1	1,400	414	8·20	1·47	4·92	15·2 19·7 Tandem two cyldrs.	33·4 Fan driven by belt.	36 46 56	123 164 186	3,141 4,064 4,789	17·12 28·15 59·88	86·400	608 787 962	52,576 655,710 832,146	0·945 1·378 2·086	4·16 4·54 4·31	7·83 14·23 28·68	20·66 21·41 22·06	0·457 0·505 0·479	
																		Means	4·33		21·30	0·480	0·734
9	Capell	No. II. Prosper, Westphalia	2½	1,440	380	12·30	6·56	6·89 Two Inlets.	20·5 Two engines coupled.	31·5 Driven by belt.	46 56 66	184 224 264	7,106 8,651 10,196	63·54 93·78 148·08	58·53	1,231 1,525 1,699	72,157 89,338 99,590	3·38 4·33 6·10	2·74 2·78 3·18	38·51 60·98 95·79	15·06 16·57 15·38	0·606 0·650 0·647	
																		Means	2·90		15·6	0·634	0·491
10		Koenigin Elizabeth	2½	700	210	8·20	5·90	4·59	15·75	23·6 Driven by belt.	40 50 60	160 200 240	4,120 5,152 6,183	6·60 14·63 24·62	39·08	704 940 1,041	27,536 36,762 40,697	1·06 1·8 2·52	2·97 3·38 3·12	4·63 10·82 16·16	10·22 10·33 9·47	0·701 0·739 0·686	
																		Means	3·16		10·01	0·698	0·534

RESULTS OF EXPERIMENTS ON FANS.—*Continued.*

Experiment Number.	Description of Fan.	Name of Colliery.	Years in Use.	Cost of Installation.		Dimension of Fan.			Dimensions of Cylinders of Engine.		Revolutions per Minute.		Speed of Periphery of Fan per Minute.	Indicated Horse-power.	Sectional Area of Air-drift where measured.	Air per Minute.		Water-gauge.		Theoretical Work of Air Displaced.	Equivalent Orifice.	Mechanical Efficiency.	Manometric Efficiency, Vacuum.
				Total.	Fan only.	Diameter.	Width.	Diameter of Inlet of Fan.	Diameter of Piston.	Stroke.	Engine.	Fan.				Speed per Minute.	Volume per Minute.	Observed.	Calculated for Rim Speed of 6,888 Feet.				
				£	£	Feet.	Feet.	Feet.	Inches.	Inches.					Sq. Ft.	Feet.	Cu. Ft.	Inches.	Ins.	H.-P.	S. Ft.		
11	Capell	Dahlbusch	½	1,380	300	11·81	5·25	7·216 Two Inlets.	17·7 Two engines coupled.	29·5 Driven by belt.	36	160	5,931	30·30	46·16	881	40,722	2·32	3·09	14·91	10·22	0·492	
											40	178	6,598	40·54		997	46,086	2·83	2·80	20·68	10·44	0·508	
											44	196	7,263	52·68		1,039	47,963	3·11	3·13	23·53	10·22	0·447	
																		Means	3·01		10·22	0·482	0·509
13	Rateau	Villebœuf (Soufflant)	1¼	1,000	420	6·56	·52	3·93	12·8	19·7 Driven by belt.	100	177	3,644	19·55	30·88	1,584	48,955	1·22	4·33	9·41	17·00	0·481	
											120	216	4,447	32·81		1,702	52,604	1·81	4·35	15·01	14·96	0·457	
											125	255	5,252	35·74		1,877	58,015	1·89	3·25	17·28	16·46	0·483	
																		Means	3·97		16·14	0·473	0·673
14		Villars	¼	1,000	380	6·56	·52	3·93	15·0	23·6 Driven by belt.	110	237	4,880	23·82	37·01	1,291	47,823	2·64	5·14	19·88	11·30	0·839	
											120	264	5,437	30·72		1,350	50,005	3·19	5·11	25·13	10·76	0·818	
											130	285	5,870	40·37		1,527	56,562	3·74	5·24	33·35	11·19	0·826	
																		Means	5·165		11·08	0·827	0·875
15		Rien du Coeur Quaregnon	½	1,200	480	9·18	·754	5·51	29·5	47·2 Driven by belt.	35	145	4,179	30·79	37·98	1,021	38,822	1·77	4·82	10·77	11·19	0·350	
											45	186	5,362	49·94		1,225	46,615	2·83	4·65	20·83	10·65	0·417	
											55	228	6,573	85·57		1,602	59,488	4·29	4·74	40·24	11·08	0·470	
																		Means	4·74		10·97	0·412	0·802
16		Montrambert de la Beraudière	1/12	1,200	580	9·18	·735	5·51	15·0	23·6 Driven by belt.	80	115	3,316	16·05	61·12	881	53,925	1·30	5·19	11·04	18·07	0·687	
											101½	150	4,326	31·83		1,115	68,249	2·05	5·60	22·02	18·29	0·692	
											114	170	4,902	41·12		1,233	75,462	2·68	5·26	31·85	17·65	0·775	
																		Means	5·35		17·97	0·718	0·907

THE UNDERGROUND VENTILATOR AT THE HANSA COLLIERY.

Die unterirdische Ventilatoranlage der Zeche Hansa. ANON. *Glückauf*, 1892, *pages* 909-911, *with two plates.*

Most of the fresh air passes down No. 2 shaft to the 664 metres level, the rest of it going on to the 700 metres level, and after travelling through the workings above those levels, it reaches by means of a blind shaft and a rise-drift the airway, and thence the ventilator.

The ventilator is placed near the No. 1 shaft, and is driven by a steam-engine with two cylinders, each 16 inches in diameter and 2 feet stroke. The power is transmitted from the engine to the ventilator by means of a belt geared 3½ to 1½.

The ventilator is placed between two walls of masonry, which are strengthened by iron clamps. Between these two walls is fixed a dome or casing of sheet-iron, forming the upper portion of the comparatively broad spiral-shaped fan-chamber. The spiral casing is continued below the ventilator, broadening out into the masonry, and ending ultimately into the discharge airway.

There are three air-channels between the ventilator and the engine-room; that of largest diameter, communicating with the suction-inlet of the ventilator, takes up the hot foul air from the engine-room, whilst the other two bring the fresh air from the downcast pit. O. S. E.

MOT SYSTEM OF WINDING BY ENDLESS-ROPE.

Étude sur le Cable de Mot. By J. DOUBY. *Le Génie Civil*, 1892, *vol. xxi., pages* 67-71, *and* 11 *figures.*

The installation described was erected at one of the shafts of the Marles collieries, Pas de Calais, in 1888. Previously, winding had been effected by flat aloes ropes, with wooden guides, and it was desired to increase the output without increasing the number of boilers in use.

Iron guides were used similar to those first adopted at Mariemont, consisting of Vignole rails, weighing 70 lbs. per yard (35 kilogrammes per metre), fastened to transverse beams dividing the shaft through the centre. Two cages run on either side of the central division, there being two guides to each cage.

In the Kœpe system, the cages are connected to the ends of a single head-rope, which passes over two pulleys at the pit-heads and around a drum worked by the winding-engine. The cages are similarly joined below by a tail-rope, the length of which is equal to the depth of the shaft. The main objection to the system is that of accentuating the gravity of an accident, as in case of a breakage of the head-rope both cages would be precipitated down the shaft.

Mr. de Mot improved this system by duplicating both head and tail-ropes, so that not only do they give, combined, double the strength necessary, but the improbability of a simultaneous breakage renders accident almost impossible; for, in the case of a single rope breaking, the remaining rope, with the aid of the safety-rope, would enable the winding to proceed. In order to obviate difference of lengthening, both head and tail-ropes themselves form an endless rope.

The head-rope consists of two round steel ropes joined at the corresponding extremities by connecting chains which work round loose pulleys at the top of the cages, so as to correct the difference of lengthening. At the same time, they are also connected by safety-chains to keep the cages from falling in case of breakage. The wire ropes used are 1·30 inches (33 millimetres) in diameter, weigh 8·8 lbs. per yard (4·360 kilogrammes per metre), and cost 7d. per lb. (1·65 francs per kilogramme).

The tail-rope is a flat iron rope, 3·74 inches by 0·98 inch (95 by 25 millimetres). The weight is 14·3 lbs. per yard (7 09 kilogrammes per metre) and the cost 4·3d. per lb. (1 franc per kilogramme).

The diameter of the drum is 14·76 feet (4·50 metres), but would, with advantage, have been smaller, from 12 to 13 feet (3·80 to 4 metres), in order to diminish the work of the machine in overcoming inertia when starting. The total weight was 5½ tons (5,645 kilogrammes), and the cost £150 (3,836·51 francs).

The total cost of the installation was £1,580 (39,938·50 francs).

At Marles, the increase in rapidity of winding was marked, but not so great as would have been the case with a deeper shaft. The time occupied in changing the tubs was greater than would have been necessary had the landing-places been suited to the system.

Besides the advantage of safety in case of breakage, the system, of course, entirely removes the possibility of over-winding. On the other hand, it is not suited for use where it is required to wind from various levels.

The author considers that for shafts of from 400 to 800 yards deep, where the extraction is only from one level, the system would prove very advantageous.

G. E. C.

BRINE SPRINGS IN THE ARGENTINE REPUBLIC.

Las vertientes de agua salada de Tapias. By EUGENIO TORNOW. *Anales de la Sociedad Cientifica Argentina, Buenos Aires,* 1892, *vol. xxxiv., pages* 206-208.

About 3¾ miles to the eastward of Tapias station, on the North Central Railway, province of Tucuman, the springs gush out in a ravine which marks the course of a dried-up burn. In the old stream-bed trickles a tiny rivulet of brackish water proceeding from other springs more to the westward, and the water from all the springs uniting into one streamlet, the whole pours itself a short distance off into the Rio Salė.

The springs visited by the author make their way through a stratum of sand and bluish-grey pebbles, and then through about 6½ feet thick of reddish clay. No. 1 on the left bank of the ravine yielding 1·98 gallon per minute, and No. 2 on the right bank 2·64 gallons per minute. The former, which the landowner has surrounded with a stone enclosure, shows a temperature of 85·4 degs. Fahr., and the latter, issuing freely, a temperature of 77·9 degs. Fahr. On analysis the water yields an average of 19·4 per cent. of salt (sodium chloride), 1·73 per cent. of sodium sulphate, 0·2 per cent. of calcium sulphate, 0·95 per cent. magnesium sulphate, the total solid residue in 100 parts by weight of water being about 21½ parts. The rainfall of the country appears to have no effect whatever on the saltness of the springs.

O. S. E.

INDEX TO VOL. VI.

Explanations.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname.

Discussions are printed in *italics*.

The following contractions are used:—

C.—Chesterfield and Midland Counties Institution of Engineers.

M.—Midland Institute of Mining, Civil, and Mechanical Engineers.

S.—Mining Institute of Scotland.

N.E.—North of England Institute of Mining and Mechanical Engineers.

N.S.—North Staffordshire Institute of Mining and Mechanical Engineers.

S.S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.